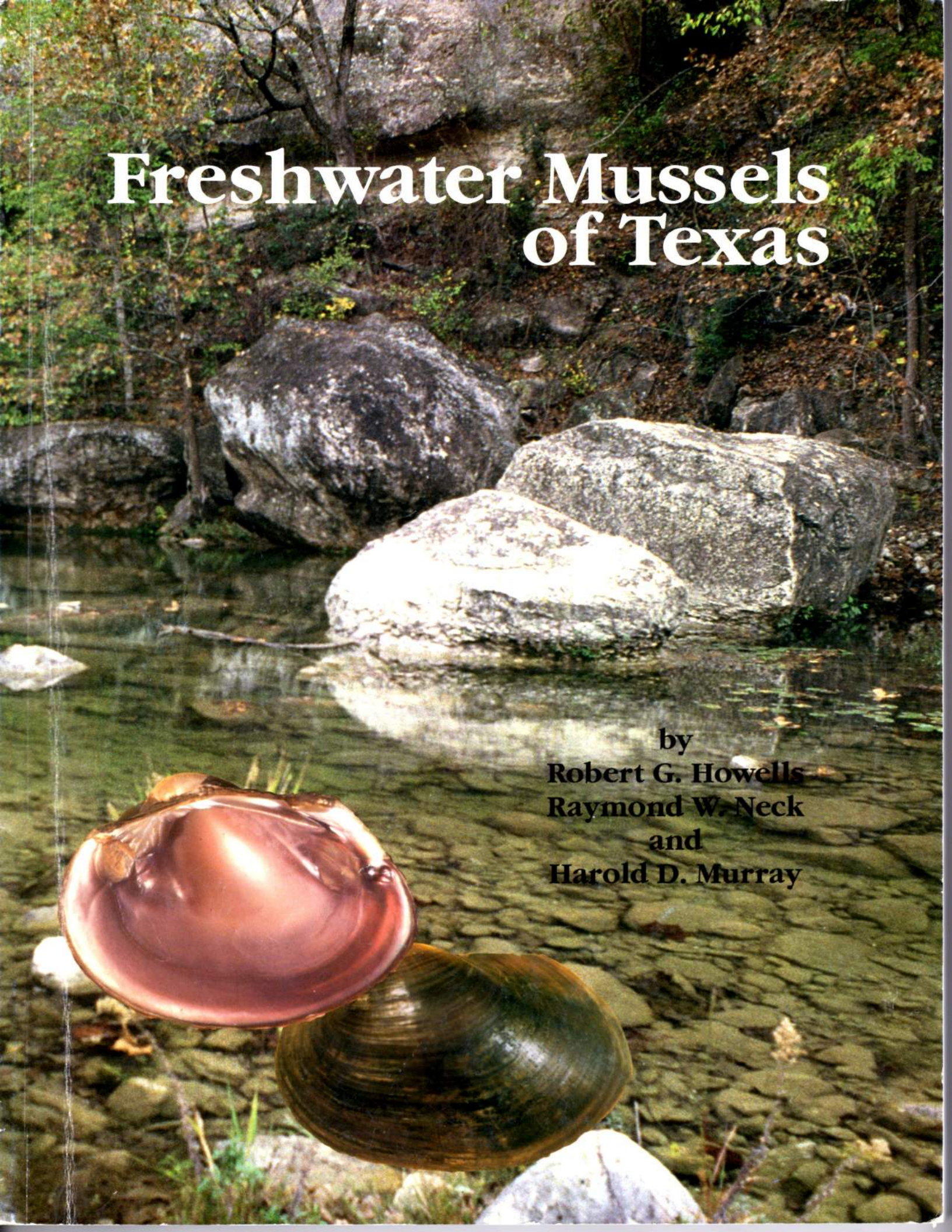
Freshwater Mussels of Texas



by
Robert G. Howells
Raymond W. Neck
and
Harold D. Murray

Front and Back Cover Photographs by Robert G. Howells

Tampico Pearlymussel (*Cyrtonaias tampicoensis*)
This pearl-producing species occurs from the Brazos River drainage south and west into northeastern Mexico. It is found nowhere else in the United States. Tampico pearlymussel attracted attention of early spanish explorers seeking pearls in Texas rivers. A pearl fishery for this species has continued through the present. Unlike many species of freshwater mussels which are in danger of extinction, this species has adapted well to some reservoirs and still maintains viable populations.

Johnson Creek, Upper Guadalupe River Drainage, Kerr County, Texas
Despite apparent natural beauty, this stream like many others in Texas has been significantly modified from its original state. Over a century of poor land and water management practices have resulted in extensive modification of most aquatic ecosystems. Freshwater mussel populations have declined dramatically in many areas and have been completely extirpated from others. Subfossil shell remains indicate Johnson Creek once held significant freshwater mussel populations. Now, none remain.

Cover Design: Suzanne Davis

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Inland Fisheries Division

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INTRODUCTION

Freshwater mussels of the family Unionidae, also known as naiads (or naiades), have inhabited fresh waters around the world for the last 400 million years (Smith 1976). They prospered in early streams and rivers long before dinosaurs and have continued to endure long after these giant reptiles passed into oblivion. Unfortunately, the continued survival of this group of unique mollusks is seriously in question. Early in the century, H.M. Smith of the U.S. Bureau of Fisheries (Smith 1919) wrote "Fresh-water Mussels: A Valuable National Resource Without Sufficient Protection" to highlight concerns about declining populations of unionids. Neves (1992) reported that among the nearly 300 North American species and subspecies, 6% are presumed extinct, 15% are currently federally listed as Threatened or Endangered, and another 23% are proposed to be listed. Similarly, Shannon et al. (1992) indicated besides the 18 species assumed extinct already, it is estimated that another 45 additional species will go the way of the passenger pigeon within the next 10 years. If unionid mussels were seal pups, pandas, whales, or song birds, the public and scientific communities alike would be outraged.

Unionids were actively harvested by Native Americans for food, tools, and jewelry, but with little apparent impact on mussel populations. Occasional "pearl rushes" prompted overharvest in some areas following discovery of gem-quality pearls, especially in the 19th and 20th centuries (Kunz 1897; Strecker 1931; Clemens 1981). Major damaging harvest occurred just before the turn of the century when mussel shells became the standard material for buttons; this industry continued into the mid-1900s and waned only after the development of plastics and depletion of many mussel beds (Coker et al. 1921). During this time, pollution, dam-building activity, and other human-related environmental alterations impacted freshwater mussel populations as well. Still, mussels survived. More recently, additional new problems threaten these animals even more. Environmental problems have, of course, continued, and in some cases worsened. Further, the development of the cultured pearl industry, which requires "beads" made of American freshwater mussel shell as a nucleus to produce cultured pearls, has also prompted massive harvest. The exotic Asian clam, Corbicula sp(p)., which competes with native mussels for food and space (Vidrine 1993), has spread throughout Texas in the last three decades. Perhaps most disconcerting of all is the invasion of the zebra mussel (Dreissena polymorpha), which entered the Great Lakes in the 1980s and is now spreading south along several major river systems including the Mississippi River. Zebra mussels can encrust native unionids and result in mortalities and shifts in population composition (Berg et al. 1992); upwards of 10,000 zebra mussels have been reported on a single native freshwater mussel (Schloesser 1992).

Despite the large number of species in the family, unionids have received relatively limited attention from the scientific community. Early taxonomists made efforts to list and classify American species. In the 1890s, the U.S. Fish Commission began scientific studies of mussels, but invariably with commercial harvest in mind (Neck 1982a). Major distributional, biological, and ecological studies have been limited. Texas in particular has been especially wanting in this area. A brief descriptive listing of species by Strecker (1931) and a number of subsequent journal articles were basically the extent of such efforts in Texas in the last half century. Indeed, when Read and Oliver (1953) reported briefly on freshwater mussels near Dallas, they specifically noted that little had been added to the understanding of unionids since Strecker's work. Among the 51 or so species of unionids found in Texas, larval stages have been described for only 55% (another 14% are described here) and fish hosts are known for only 47% (with several others added here) [RGH]. With the increased pearl-shell harvest and impending zebra mussel invasion (zebra mussels reached Mississippi and Arkansas in 1992), the need for baseline reference material was clear.

This publication provides an introduction to the unionid mussels of Texas with descriptions of each and a general overview of the family, as well as brief descriptions of other bivalves which may occur in the fresh waters of the state. Sadly, terms like "unreported" and "undescribed" appear far too many times herein; efforts are now being made to fill some of these voids.

ABOUT THIS GUIDE

This guide is intended to represent not the final word on unionid mussels in Texas, but rather a starting point. At present, no reference is available which pulls together descriptions, illustrations, and distributions of the state's freshwater mussel fauna. Additionally, several bivalve species of other families which occur in Texas have been considered as well; this includes several low-salinity estuarine species and the introduced Asian clam. Zebra mussel, which is projected to invade Texas in the near future, is also included. A glossary of terms is presented following the species accounts.

Species accounts are arranged in similar formats, and presented in alphabetical order based on scientific names. Common and scientific names are presented, usually following recommendations of the American Fisheries Society (Turgeon et al. 1988); additional common or colloquial names have been included as well. Because classification has often been confused and scientific names have changed over time, a synonymy list has been provided to assist in recognizing synonyms in other publications. This list may not necessarily be complete and is not intended to be the definitive word on the subject. Synonymy references have usually been collectively cited at the beginning of each subsection; authors of specific epithets have generally been omitted from the literature cited, but can be found among one or more of the references provided. Unpublished information from the authors has been designated by initials indicating the source of the data. Where possible, photographs of Texas specimens are presented with shell lengths (sl) to the nearest whole mm. Photographed specimens are from the Houston Museum of Natural Science (HMNS), Trinity University collection (TUC), or Texas Parks and Wildlife Department's Heart of the Hills Research Station (HOH), unless otherwise indicated.

Distribution has been largely taken from unpublished lists prepared in April 1992 of museum collections, literature citations, or by collections made by the Texas Parks and Wildlife Department (TPWD). Description sources have also been cited collectively at the beginning of each subsection, except where specific points required individual citation for clarity and accuracy. Collective citation varies from accepted procedures used in scientific journals, but was used here to reduce text volume. Where additional unpublished points are inserted, the appropriate author's initials are indicated. Descriptions include sizes reported, general shell features, shell teeth, internal and external colorations, and soft tissues. Habitats are described, as is spawning season and method, if known. Glochidia are described when either published descriptions are available, or gravid females were obtained during preparation of this manuscript. Host fishes are indicated where known. Importance, especially commercial and sport importance, is discussed where applicable. Dashed lines have been used on range maps to indicate uncertain distributional limits and disjunct collection sites have been circled for clarity.

Well-known species for which good descriptions are readily available in the published literature, are sometimes discussed more briefly than some local endemic or nearly-endemic mussels for which complete, recent published descriptions are otherwise difficult to obtain. Similarly, species whose glochidia have not previously been discussed have occasionally been described in somewhat greater detail. For example, Tampico pearlymussel (Cyrtonaias tampicoensis) and southern mapleleaf (Quadrula apiculata) are common in many areas of Texas, yet have not been included in recent descriptive books on American unionids; therefore, these species are afforded additional attention herein. The following introductory discussion focuses on unionid mussels; similar aspects for other bivalves in different families are discussed under those species accounts.

ANATOMY

Perhaps one of the reasons some scientists have avoided working with unionids reflects their extreme, almost plastic, variability. Experts have debated for years over classification and relationships of many species. One of us (RWN) may well have characterized work on freshwater mussel biology (in a letter to RGH 28 August 1992) when he referred to the "ever-maddening variability that makes unionids so interesting and frustrating at the same time." Valentine and Stansbery (1971) indicated they had "never seen a group with so many challenging problems" and that "when specialists disagree, as they often do in the study of unionids, the beginner can become lost in the controversy." Discussion of bivalve anatomy and physiology is available in numerous sources. For details beyond the brief overview presented below see Coker et al. (1921), Pennak (1953), Clench (1959), Murray and Leonard (1962), and Oesch (1984).

Shell

The most obvious characteristic of all freshwater mussels is their shell (Figs. 1-3), which is composed of left and right halves or valves. The nonliving shell contains both inorganic and organic components and is made of three major layers and a fourth additional layer associated with interior muscles. The outermost layer, called the periostracum or epidermis, is thin and proteinaceous in nature. Below the epidermis is the prismatic layer made of calcium carbonate (calcite). The third and innermost layer of shell is the nacre or mother-of-pearl layer visible inside the shell; it is composed of calcium carbonate in the form of calcite, aragonite, or both, in alternating layers, and is the thickest of the three major layers. Additionally, a fourth layer called the hypostracum is present at the attachments of the major muscles, and is similar in nature to the nacre; it is very thin (Coker et al. 1921). The three major layers are secreted by the mantle and the hypostracum is produced by its associated muscles. Often a surprising amount of damage can be sustained by these various shell layers without affecting survival of the animal. Many species display extensive erosion to some areas of the periostracum and calcium carbonate layers, especially at the beaks. In response to extreme shell loss, particularly erosion due to acidic waters or mechanical damage, the freshwater mussel may secrete new material to repair a hole or reinforce areas of thin shell.

Externally, shells may be very smooth or heavily sculptured with small pimples, larger pustules, heavy ridges and grooves, or other features. Such external sculpturing is often highly variable with dramatic development in some individuals, but other individuals in the same population may be almost completely smooth. Shell shape is often diagnostic, but is also often quite variable. Additionally, some individuals, sexes, or species may be strongly compressed from side to side, hence very narrow, or strongly inflated and nearly globular in cross section (Fig. 2). Internally, shells have a number of features that may be important in identification. Left and right shell halves are held together by a strong ligament placed along the hinge, typically behind the beaks, and by major muscles positioned internally. Additionally, most unionids have toothlike structures adjacent to the hinge. These include elongate lateral teeth parallel to the hinge and pseudocardinal teeth positioned near the beak. Teeth are usually double in the left valve and single in the right, but several species lack these structures.

In addition to typical sculpturing unique to each species and natural erosion that sometimes occurs, definite growth and rest period rings or lines are also present in the shell. These growth rings may or may not be readily discernable externally. Further, growth rings may or may not be annular marks, and false annuli may be present. Coker et al. (1921) reported that simply handling mussels to measure sizes could result in development of a minor ring. Neves and Moyer (1988) presented a review of methods of analyzing and interpreting mussel age from these growth rings. Although a number of researchers have examined growth rings and attempted age estimates from them, many such studies lacked validation, and virtually none have been performed on mussel populations as far south as those in Texas.

Soft Tissues

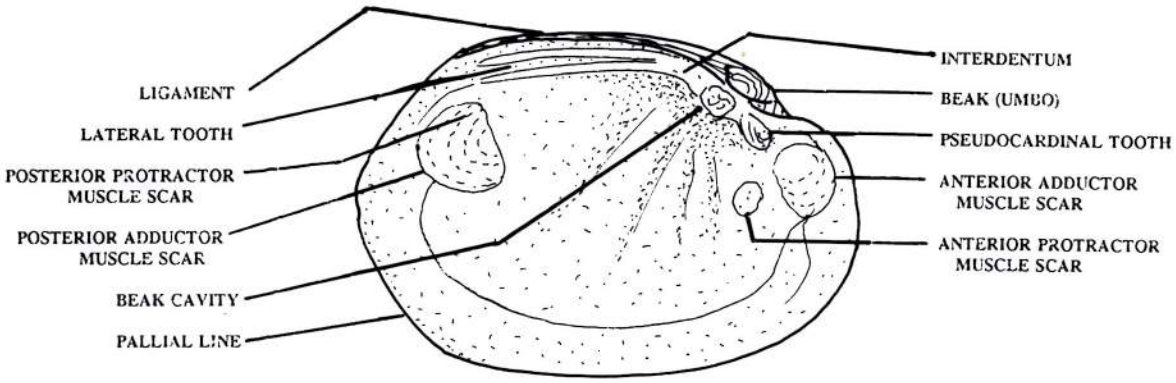
Shell Muscles:

Among the major muscles (Fig. 4), the two largest are the anterior and posterior adductor muscles which connect the right and left valves and serve to close the shell. One and sometimes both of these must be cut in order to open the shell. Two smaller muscles, the anterior and posterior retractor muscles extend from the shell and attach to the body and foot; they help retract the foot into the shell. The anterior protractor muscle aids in extending the foot. Retractor muscles sometimes combine with adductor muscles

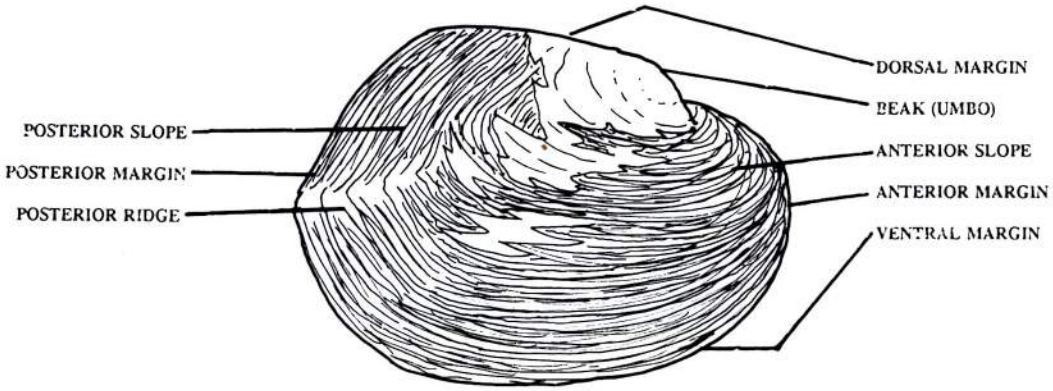
Mantle:

The mantle (also called pallium) lines the interior of the valves and encloses the body of the freshwater mussel (Fig. 4). It is relatively thin and fragile in many species. The mantle secretes the shell, contains sensory organs, and aids in respiration and feeding. The three primary shell layers are secreted by the mantle at or near the margin (Coker et al. 1921). The area between the mantle and other soft tissues is the mantle cavity. Incurrent and excurrent siphons are formed posteriorly by the mantle.

INTERNAL SHELL FEATURES



EXTERNAL SHELL FEATURES



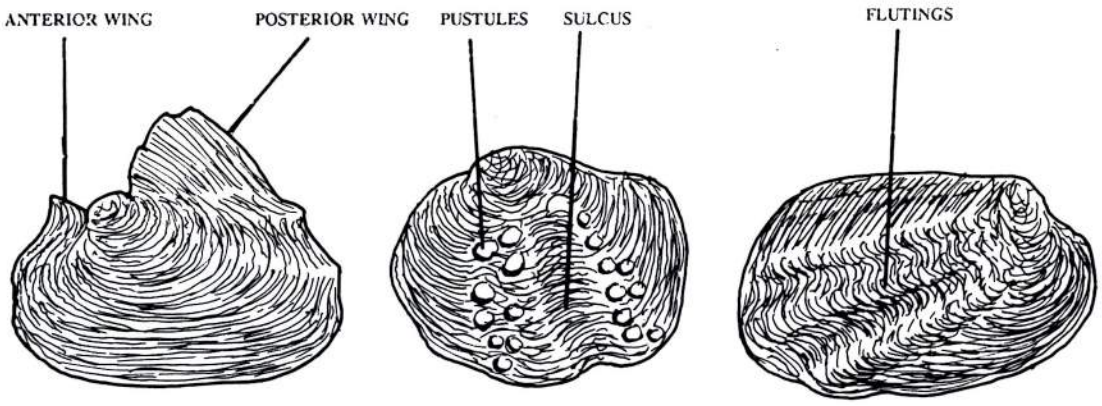
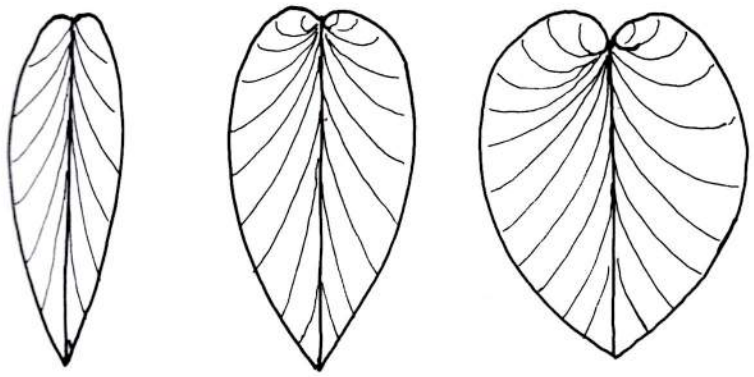


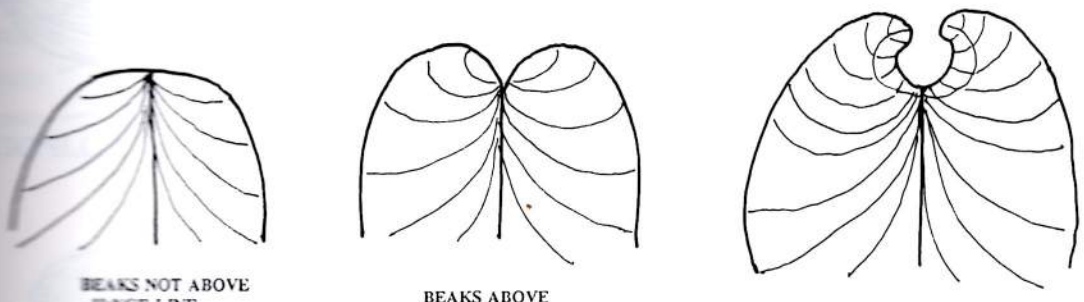
Figure 1. Internal and external features of freshwater mussel shells.

SHELL WIDTH



COMPRESSED NORMAL INFLATED

BEAK MORPHOLOGY



BEAKS NOT ABOVE HINGE LINE

BEAKS ABOVE HINGE LINE

BEAKS ELEVATED AND HOOKED

SHELL FEATURES (NON-UNIONID BIVALVES)

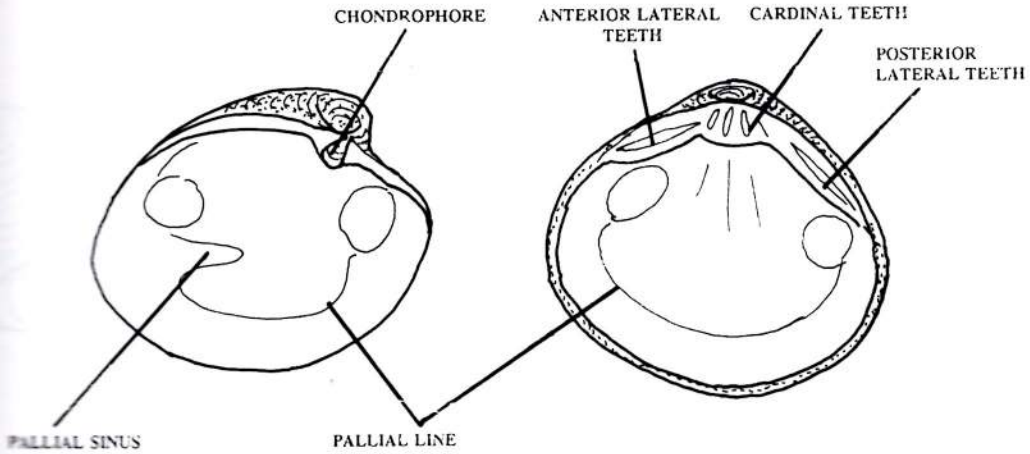
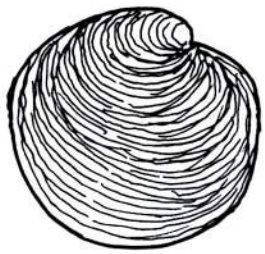
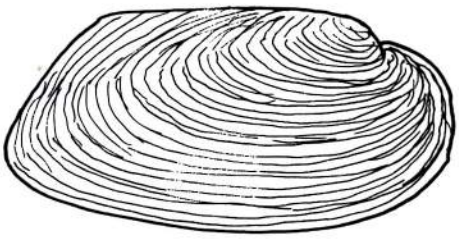


Figure 2. Examples of shell width and beak morphology of freshwater mussel shells and shell features of non-unionid bivalves.

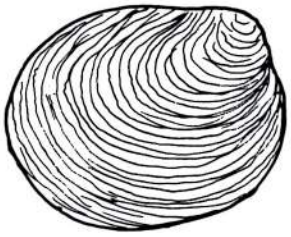
SHELL SHAPE



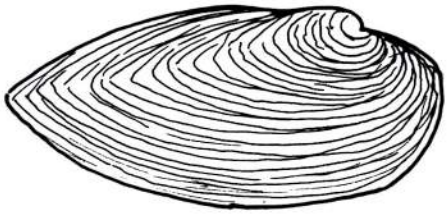
ROUND



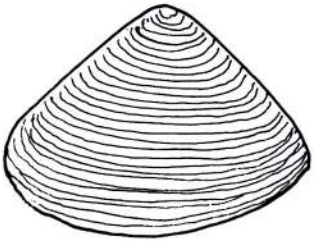
RHOMBOIDAL



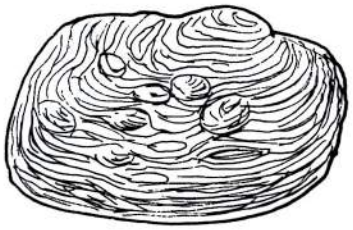
OVAL



ELLIPTICAL

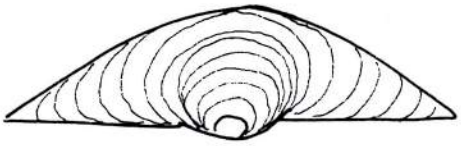


TRIANGULAR



QUADRATE

BEAK SCULPTURING



SINGLE LOOPED

DOUBLE LOOPED

Figure 3. Examples of freshwater mussel shell shape and beak sculpturing.

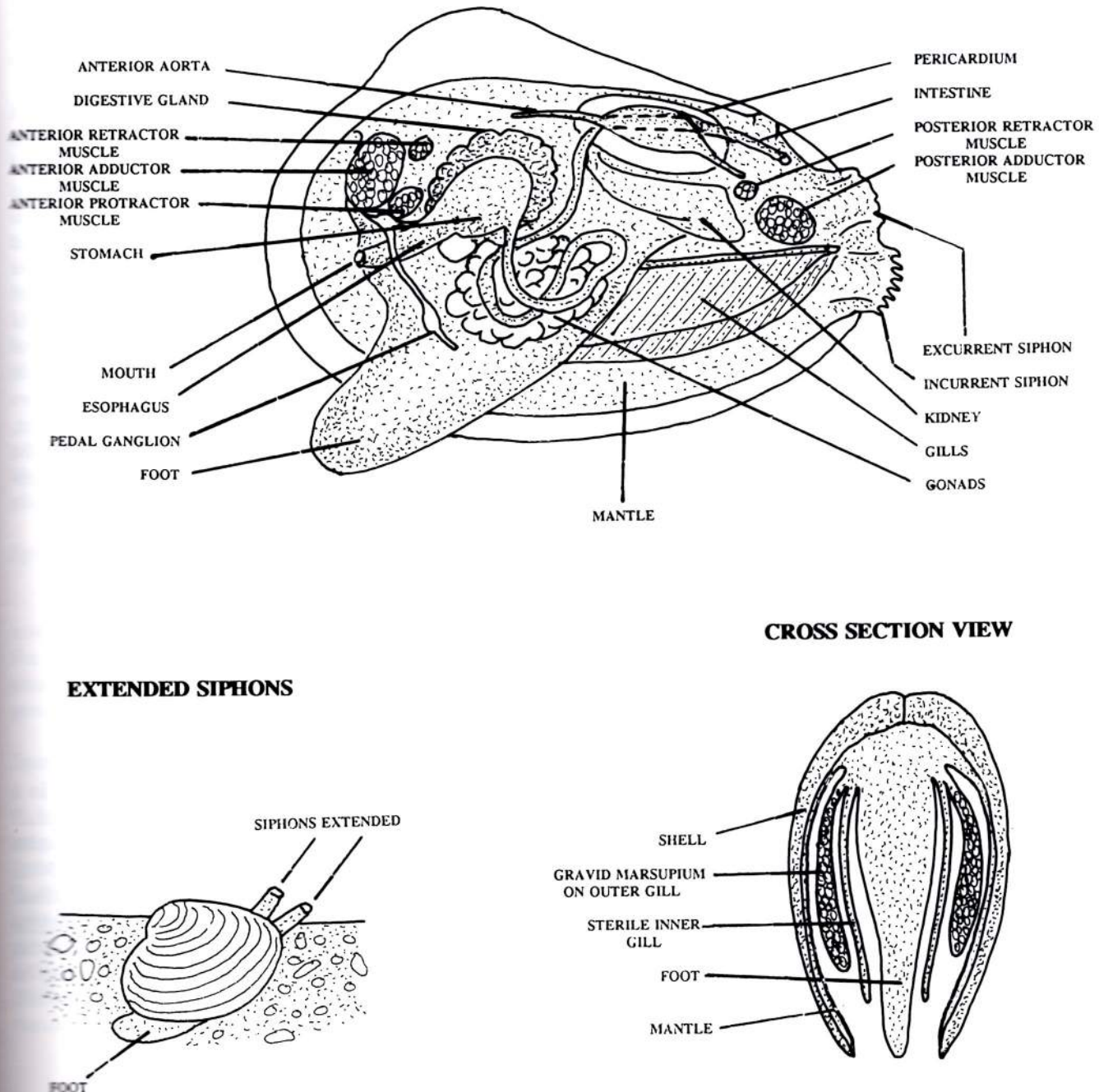
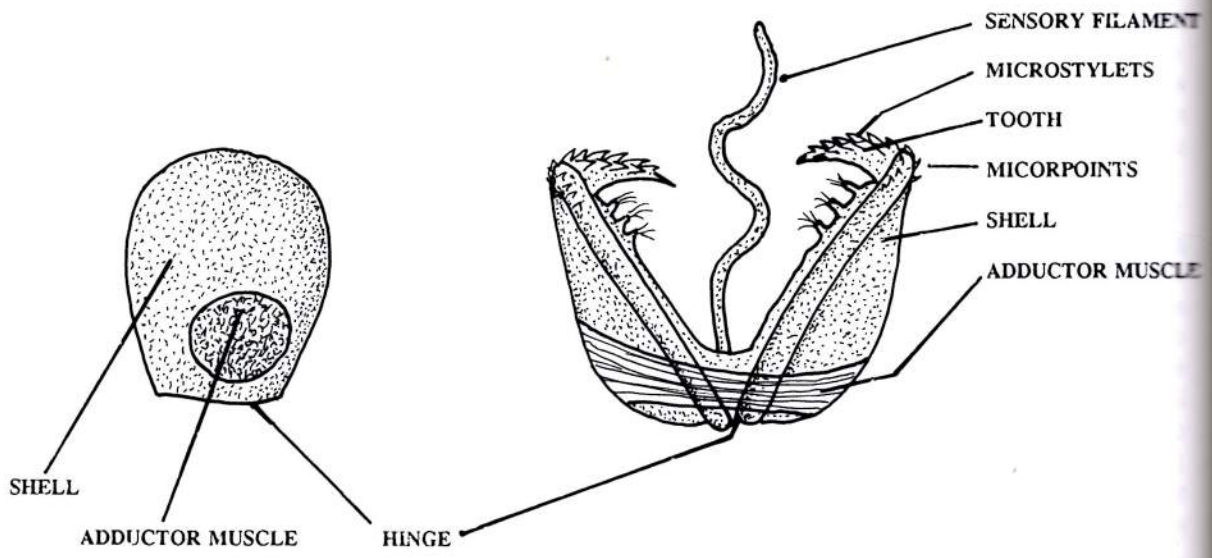


Figure 4. Freshwater mussel internal soft tissue anatomy.

UNIONID MUSSEL GLOCHIDIA



NON-UNIONID MUSSEL TROCHOPHORE LARVAE

NON-UNIONID MUSSEL VELIGER LARVAE

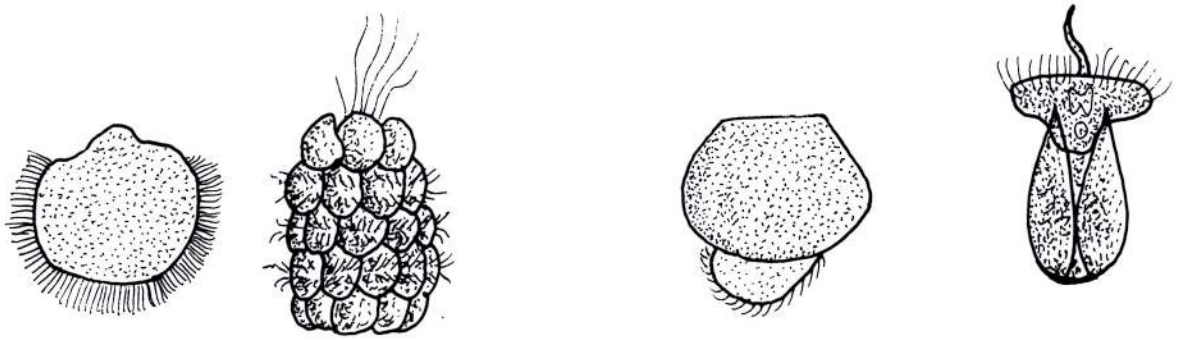


Figure 5. Unionid mussel glochidia and non-unionid mussel trochophores and veligers.

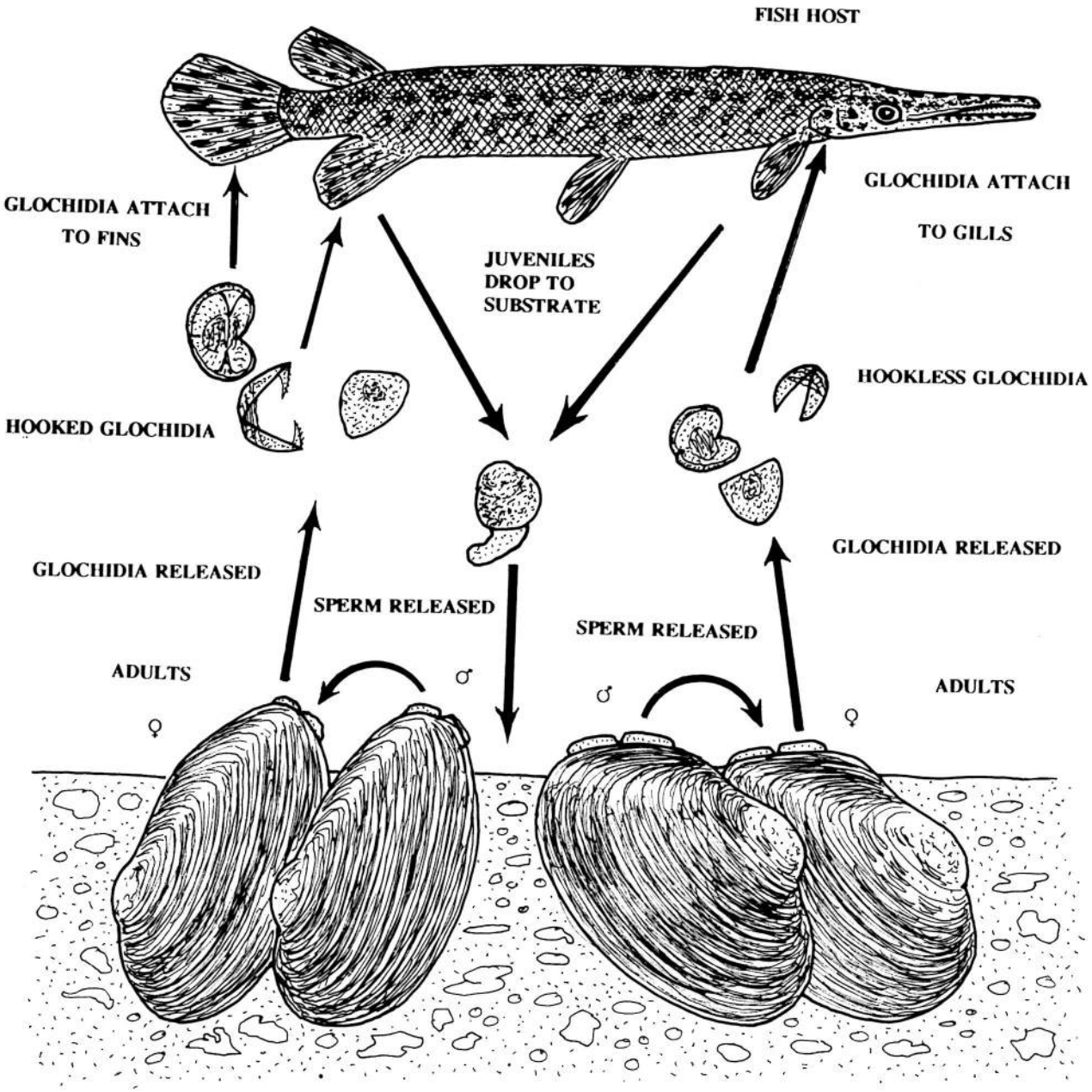


Figure 6. Freshwater mussel reproductive cycle.

Glochidia and Parasitism:

Mature glochidia are small, ranging from 0.005 x 0.052 mm in spectaclecase (Cumberlandia monodonta) to 0.290 x 0.355 mm in purple wartyback (Cyclonaias tuberculata) (Oesch 1984). Most are generally round or oval in shape. They consist of a pair of valves that are hinged dorsally and held by an adductor muscle; a sensory byssus thread or filament is also often present and may serve to detect hosts (Murray and Leonard 1962).

Glochidia are grouped into two (Oesch 1984) or three (Coker et al. 1921; Murray and Leonard 1962) basic types based on general shape and presence or absence of spines or hooks (Fig. 7):

- Hooked or spined glochidia possess fang-like spines on the ventral edges of the valves that assist in attachment to host fish fins. Floaters (Anodonta spp.), squawfoot, and white heelsplitter have hooked glochidia.

- Hookless or apron glochidia lack these fang-like spines on the valves and are typical of most commercial mussels like washboards.

- Axe-head glochidia, a third type recognized by some authorities, are roughly axe-head in shape and may have small prong-like hooks on the edges of their valves. Heelsplitters and other members of the genus Potamilus have this glochidial type.

Some glochidia may be released singly by the female or in groups, depending upon the species (Buchanan 1980). Certain mussels may discharge conglutinates containing glochidia which may in turn be eaten by fishes; conglutinates may actually resemble worm- or grub-like food items (Oesch 1984). Other mussels may release glochidia when consumed by mussel-eating fish (Oesch 1984). Accordingly, species like freshwater drum (Aplodinotus grunniens) and channel catfish (Ictalurus punctatus), which consume mussels as part of their diet, are often heavily infested (Murray and Leonard 1962). Additionally, some mussels may release glochidia or conglutinates in response to passing shadows, and in others, hanging flaps of soft tissue extending from the female's mantle may attract fishes directly, or indirectly by first attracting aquatic invertebrates (Coker et al. 1921).

Glochidia cannot swim or crawl after release but must drift with water currents (Buchanan 1980; Oesch 1984). Hooked glochidia react by contracting forcefully upon contact with a host fish's fins; however, hookless forms react to physical stimulation less but will respond violently when blood is present in the water (Oesch 1984). Indeed, both blood and salt can provoke an active snapping reaction when added to water containing glochidia (Coker et al. 1921).

Glochidia which do not contact a suitable host fish within a few days will die (Coker et al. 1921; Buchanan 1980). Glochidia which attach to an improper host species or occasionally hooked glochidia which attach to mouths or gills (rather than fins) may be sloughed off within a few days to die. Those which locate and attach to an appropriate host fish may become encysted within as little as five hours but usually within 24-36 hours (Lefevre and Curtis 1910). The duration of the parasitic stage varies greatly and may last 7 -193 days, depending upon water temperature, mussel species, and host species (Lefevre and Curtis 1910; Coker et al. 1921).

Lefevre and Curtis (1912) and Stein (1968), reported fish previously infected with glochidia appeared to develop an immunity to reinfection. Glochidia attaching to a previously infected fish are often sloughed off much like those attached to inappropriate hosts. Further, this immunity may apply to protection from infection by certain potentially more harmful parasitic copepods as well (Coker et al. 1921). Stein (1968) found bluegill (Lepomis macrochirus), which had been previously infected with glochidia that same season, would slough-off newly attached glochidia within two days.

The number of glochidia produced by a single female may vary, often from 75,000 to 3,000,000 (Coker et al. 1921). A 74-mm shell length fragile papershell (Leptodea fragilis) reported by Coker et al. (1921) contained 2,334,000 glochidia.

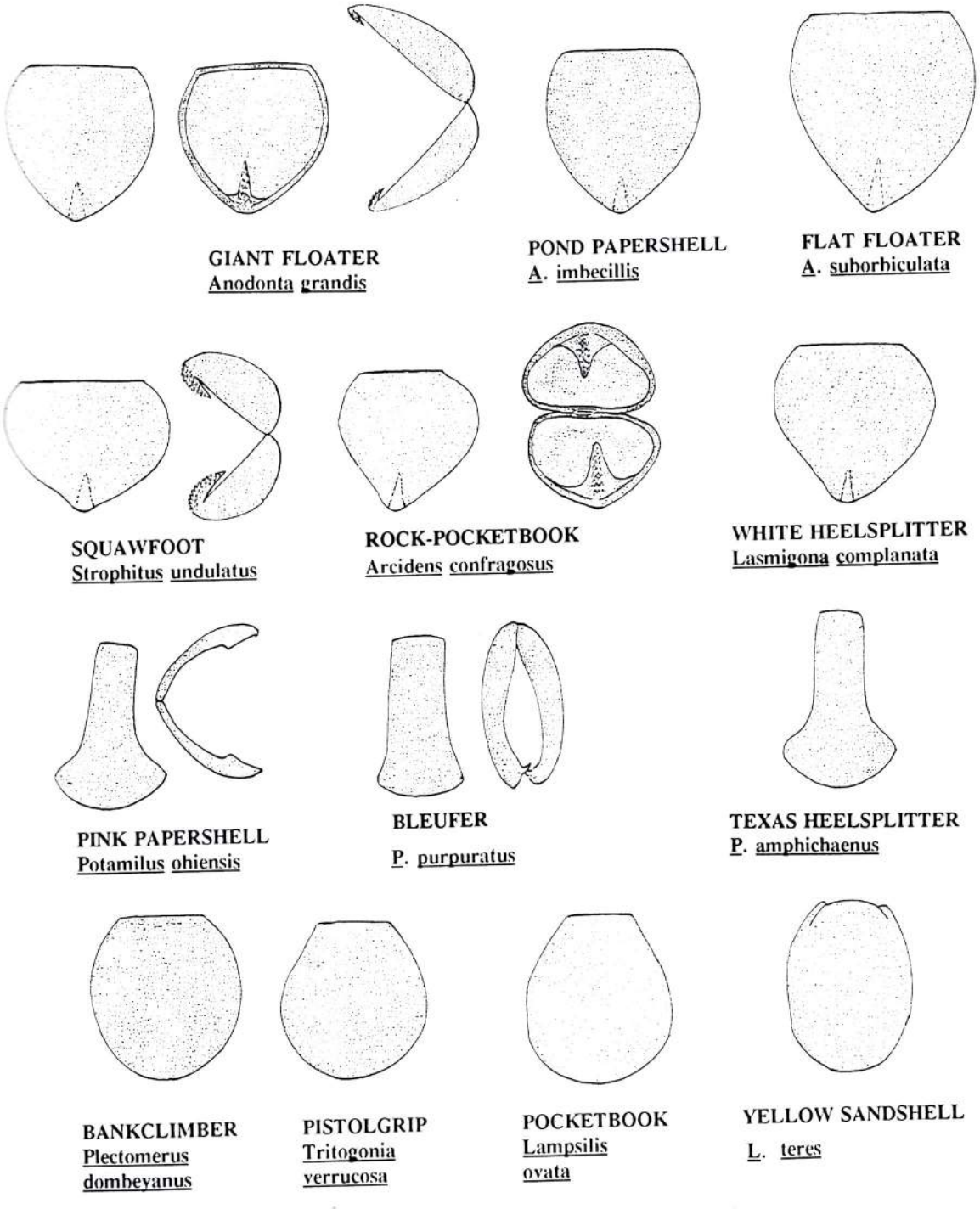


Figure 7. Examples of freshwater mussel glochidia.

Infections are usually light (Murray and Leonard 1962). Encysted glochidia grow little during the parasitic stage; hence, impact on the host fish is generally minimal. A few species do grow during this period and may impact the host more (Coker et al. 1921). Among 324 fish examined in one study, only 8.9% were found to be infected, with 1 - 416 glochidia per fish and an average of 125 (Coker et al. 1921). Surber (1913) reported up to 3,740 ebonyshell (Fusconaia ebena) glochidia on a single skipjack herring (Alosa chrysochloris); similar heavy infestations may occur on freshwater drum (Coker et al. 1921). Infections on small fishes may cause lacerated and inflamed gills with subsequent death in rare instances (Lefevre and Curtis 1912).

Juveniles:

During the parasitic stage, encysted glochidia develop adult structures, but usually do not appreciably increase in size (Murray and Leonard 1962). Because most glochidia grow little during the parasitic stage, released juveniles are often no larger than the previous glochidial stage (Coker et al. 1921). Juvenile mussels released on inappropriate substrates do not survive. In general, the biology and microhabitat requirements of early juveniles under natural conditions are poorly known (Coker et al. 1921).

Adult and subadult unionid mussels do not possess byssus threads (for substrate attachment) present in marine and estuarine bivalves of several families. However, some juvenile unionids do secrete a byssus thread to assist in attachment early in the juvenile stage, especially in Lampsilinae (Coker et al. 1921). Some species whose juveniles do produce byssus structures include yellow sandshell (Lampsilis teres), fragile papershell, pink papershell, deertoe (Truncilla truncata), and threeridge. This juvenile byssus is eventually shed in freshwater mussels (Coker et al. 1921).

Habitat

Water-body Types:

Freshwater mussels may inhabit a variety of water-body types including large and small rivers and streams, lakes, ponds, canals, and reservoirs. More stable habitats may have larger and more diverse populations than do smaller and less stable waters. Some species tolerate a wide variety of conditions, but others may be more specific. Certain mussels may require moderate to swiftly flowing waters, and typically fail to survive in lakes or impoundments. Headwater spring pools and streams in the Texas Hill Country typically harbor few if any mussels largely because the cool, clear waters lack sufficient phytoplankton and other foods needed to support mussel populations. A few species like pondhorns (Uniomerus spp.) occur in temporary ponds and periodically-dry portions of intermittent streams by burrowing into the substrate during dewatering. Coker et al. (1921) indicated the greatest number of species and individuals often occurred in flowing waters, and in areas of strong currents; however, they also noted some river stretches were sometimes completely lacking mussel populations. Coker et al. (1921) also concluded the presence of fish frequenting eddies and slackwater areas adjacent to faster currents may be related to the frequent presence of mussels nearby.

Bottom Types:

Deep shifting sand and deep soft silt are among the most limiting bottom types for mussels. Similarly, bedrock and heavy boulder and cobble bottoms are often poorly populated. Shifting sands may change too frequently for slow-moving but long-lived mussels. Heavy-shelled species can smother in deep silt; however, some thin-shelled floaters can survive on silt bottoms by actually laying on the surface rather than digging into the substrate (Coker 1919). The impoundment above Ingram Dam, Kerr County, for example, is inhabited only by paper pondshell and Asian clam. Paper pondshells are sufficiently light-shelled to allow them to rest horizontally on the bottom, but heavier, more-rounded Asian clams actually sink into the soft silt producing a cratered moonscape appearance to the bottom. Bare bedrock and boulder bottoms may be sparsely populated by mussels swept there from adjacent areas. Mussels may occur in sand and gravel patches found in cracks or in slack-water areas among the rocky stretches. Many areas of the middle and upper Llano River in central Texas are largely comprised of deep shifting sands, bedrock, and heavy cobble stretches which are inhospitable to mussels.

Mud, sand, gravel, and cobble, and combinations of these, are often the most heavily populated substrates. Flow obstructions like fallen trees, logs, and gravel bars may provide protected habitats for mussels in some situations.

Fuller (1974) considered siltation associated with poor agricultural practices and general deforestation as a major negative factor impacting mussel communities. Some mussels may be unable to endure silt overlays greater than 0.6 cm (Ellis 1936), other species may emerge through silt overlays up to 18 cm thick, and mussels may need to emerge from such silt overlays within a few hours or die (Marking and Bills 1980). Silt may also impair filter-feeding efficiency.

Current:

Mussels may be found in currents ranging from no-flow pond or lake situations to rapidly flowing streams and rivers. Species like paper pondshell, pondhorn (Uniomerus tetralasmus), and pond mussel (Ligumia subrostrata) are especially well adapted to still-water situations in ponds and small reservoirs. Other mussels may require moderate flow rates, and may endure poorly, if at all, in impounded waters. Washboards generally occur in larger flowing rivers but can survive quite well after impoundment if other necessary conditions are present.

The Texas Hill Country just north of the Balcones Fault presently has stretches of several rivers which are especially depauperate of mussel populations (e.g., portions of the Medina, Guadalupe, and Llano rivers). The paucity of mussels in these areas, in part, reflects the extreme scouring that occurs during severe floods. This scouring produces bottoms of bedrock, heavy rock rubble, or deep-shifting sands which are inhospitable to mussels, and dislodges them from the substrate. The Guadalupe River from above Ingram to below Comfort produces occasional subfossil shells but supports few, if any, extensive heavy-shelled, long-lived species. Paper pondshell is often the only unionid present at such locations and then may be restricted to rapidly silting areas behind small dams. Collections of freshwater mussels in these rivers in the early and middle portions of the 20th century demonstrate the present paucity of mussels is a recent phenomenon.

Water Depth:

Unionids often become scarce below depths of about 7.6 m (Coker 1919). Mussel populations in some Texas reservoirs, which have maintained low water levels for a period of years and then were quickly filled, or which are periodically drawn down below normal pool level, may have major mussel concentrations at atypically deep locations. For example, Lake Buchanan, Llano and Burnet counties, maintained low levels for several years, but was filled by heavy rainfall during early 1992; musselers report populations now rare above about 10 m. Similarly, Inks Lake, Llano and Burnet counties, is normally drained to about 3 m below normal pool level during winter every other year for maintenance and repair activities. Sampling by TPWD in summer 1992 found few live mussels but many shells at depths less than 3.7 m; however, sport and commercial harvest continued in deeper waters. Water-level fluctuations related to drought and rainfall, as well as deliberate drawdowns, appear to have major impacts on mussel distribution and populations in several Texas reservoirs, and sometimes result in mussels occurring at greater depths than would be typical in more natural situations. Mussel kills can occur following increases in reservoir levels and have been associated with silt deposition, oxygen depletion, or both.

Coker et al. (1921) reported temperature changes associated with depth had little effect on mussel distribution, but wave action could impact individuals in shallow waters. They noted that mussels were frequently abundant in very shallow waters when conditions were favorable.

Water Chemistry and Clarity:

Water chemistry and quality can be a major factor in mussel abundance and distribution. Dissolved oxygen levels below about 20% saturation can stress freshwater mussels (Ellis 1937; Ingram 1957). However, many species can apparently endure brief periods of low oxygen levels; threeridges were reported to survive conditions of no dissolved oxygen for 10 weeks (Imlay 1971). Mineral-poor soft waters often contain few mussels, and many of these individuals have badly eroded shells (Coker et al. 1921). Thin and dwarfed shells are often associated with calcium deficiencies (Coker et al. 1921). Woortman (1926) indicated captives opened in response to aerated aquarium water, but closed when exposed to "poorly ventilated water."

Coker (1919) indicated pink- or purple-nacred species often occur in shallow clear waters while some species in deeper, turbid waters are white nacred. However in Texas, Tampico pearlymussels and bleufers with boldly colored nacres commonly occur in turbid waters like those in Lake Gonzales, Gonzales County, and Nasworthy Reservoir, Tom Green County, along with southern mapleleafs which have white nacres.

Aquatic Vegetation:

Mussels often avoid densely vegetated and heavily shaded areas; however, open patches of vegetation may be favorable to some species (Coker 1919). Juveniles are sometimes abundant in vegetation, especially species whose fish hosts are closely associated with aquatic macrophytes (Coker et al. 1921).

Associated Animals:

A variety of other animals may associate with mussels, especially in situations of large, stable beds. Coker et al. (1921) listed sphaeriid clams, bryozoans, snails, flatworms, leeches, aquatic insects, and crayfishes as common associates. Other species include gammaridean amphipods and a variety of small and juvenile fishes [RGH].

Natural Transport and Relocation:

Although certainly mussels can move limited distances through or across the substrate, such locomotion probably has limited value in general species distribution. Riverine populations may experience displacement during flood conditions. Some individuals may ultimately be deposited on acceptable substrates and continue to survive; others may die when left stranded on inhospitable bottom types or on normally exposed river banks. Musselers who regularly work Texas rivers have reported mussels washed from deep holes to shallower down-stream areas during high-water periods. Neck (1982a) indicated wading birds may transport mussels when inadvertently trod-upon specimens clamp to a bird's foot; however, such relocation is generally inconsequential.

Juveniles having completed development while encysted on a host fish may be released potentially long distances from the initial point of infection. Indeed, the parasitic nature of the unionid glochidial stage is probably a major contributor to mussel distribution.

Transport and Relocation by Man:

During a survey of mussel license holders in Texas in early 1992 (Howells 1993), several musselers indicated they had relocated mussels from one location to another. Some indicated they introduced desired species into new reservoirs or reintroduced them into reservoirs which had experienced major draw-downs and subsequent mortalities. One respondent reported moving mussels to "hide them from other musselers." Perhaps most disconcerting were those musselers who indicated when an apparently diseased bed was located, they selected specimens they judged to be unaffected and relocated them to other waters. Thus far, this practice seems to have had little or no reported significant impact on species distribution or spread of mussel diseases.

Introductions of mussels outside their native ranges have generally been few and have never been associated with the same negative impacts observed for relocated Asian clams or zebra mussels. None the less, such relocations pose potential ecological and legal risks. In Texas, the Texas Fish Farming Act of 1989 (S.B. 1507) specifically prohibits introduction of any fishes, shellfishes, or aquatic plants into state waters (except for native bait fishes) without permission from TPWD. Further, the federal Lacey Act may apply to some such introductions, thus resulting in a violation of federal statutes as well.

Fish stocking may also release glochidia into new waters introducing mussels outside their native ranges. This type of introduction appears to have happened on at least two occasions in Texas (Metcalf and Smartt 1972; Neck 1982a). Similarly, a pond in which mussels had not previously been present at TPWD's Heart of the Hills Research Station was drained in 1992 and found to contain a large population of floaters several years after fish from a local reservoir had been introduced [RGH].

Lastly, some mussel-harvest methods may contribute to mussel relocation. Use of brails and, to a lesser extent, dredges may collect mussels from a variety of areas during a long-distance drag with dropped or released

animals being ultimately deposited at locations far from the site where they were originally buried. Similarly, mussels harvested by nearly any method, then later culled and released, may be deposited at substantial distances from original collection sites.

Feeding and Food

Freshwater mussels are filter feeders and require a rich, plentiful food supply comprised largely of diatoms, desmids, filamentous algae, other algal species, and possibly detritus (Coker et al. 1921). Additionally, mussels appear to be able to make use of nutrients in solution (Churchill 1915). Studies by Coker et al. (1921) found no differences between stomach contents in different mussel species. Coker et al. (1921) also indicated some individuals suspected dense mussel beds reduce accumulating amounts of phytoplankton but they believed many phytoplanktonic species could reproduce more rapidly than they could be eaten.

Growth

Stansbery (1967) characterized growth among three unionid subfamilies in Lake Erie, Ohio, as (a): Ambleminae being typically slow growing, but commonly living to over 20 years of age, with individuals having over 40 annular rings; (b) Anodontinae being rapid growers with shorter life spans like paper pondshell which matures at two years of age but rarely lives beyond five years; and (c) Lampsilinae being intermediate between the two other subfamilies with growth being rapid in juveniles but slow in adults, with maturity at three years in shallow waters and at four to six years in deeper waters. Similarly, Buchanan (1980) indicated thin-shelled species often live 4-10 years, but thick-shelled mussels may live 20-40 years, or more. Growth may be directly proportional to shell thickness, so mineral requirements may be more limiting than organic food (Coker et al. 1921). Additionally, riverine populations may contain larger, older, and slower-growing cohorts (Neves and Moyer 1988) than similar populations in lakes or reservoirs.

Examples of shell length for several species in Iowa (Coker et al. 1921) include the following:

Giant floater: 66-88 mm at 16 months,
Paper pondshell: 64-67 mm at 16 months,
Pink papershell: 78-81 mm at 16 months or less,
Fragile papershell: from 17.6 to 107 mm in 2.5 years,
Yellow sandshell: 41.0 mm at the end of the second summer,
Fawnsfoot (Truncilla donaciformis): 20.0 mm at the end of the second summer,
Threehorn wartyback: 16.0 mm at the end of the second summer,
Threeridge: 13.5 mm at the end of the second summer, and
Pimpleback (Quadrula pustulosa): 14.2 mm at the end of the second summer.

Growth rates vary not only between locations, species, and characteristic shell thicknesses, but also with age and maturity. As with many animals, growth is often fastest prior to the onset of sexual maturity (Chamberlain 1927). Coker et al. (1921) suggested an average annual growth for medium-sized quadrulids of about 6 mm/year; Isley (1914) indicated only about 1 mm/year for larger individuals in riverine conditions. Lefevre and Curtis (1912) reported a nearly-mature hickorynut (Obovaria sp.) gaining only 5 mm in 2.5 years. In a study of 521 specimens of four species in Virginia, Neves and Moyer (1988) found many individuals grew less than 1.0-1.5 mm/year.

Determining the age of unionid mussels has been problematic. They do produce growth-rest period bands in the shell which may be yearly developed annuli, but false annuli can be produced as well. Neves and Moyer (1988) found annulus formation in Virginia occurred between January and May. Most studies of growth and aging have focused historically on the upper Mississippi River valley, with little investigation in Texas or at other locations of similar latitudes. Mild winters which could allow continued growth or summer droughts that could halt or slow growth could produce growth-rest marks which may be more easily misread than in similar specimens taken at northern locations where winter and summer periods are much more clearly defined. Estimates from some shell buyers of washboards from northeastern Texas well over 100 years old are not verifiable, and may not be accurate.

Behavior

Movement:

Although all unionids have a foot that functions for locomotion, ability to move varies greatly among species. Heavy-shelled mussels like mapleleafs (Quadrula spp.) may be unable to help themselves if conditions become unfavorable (Coker 1919). Heavy, rotund forms may be less active than more slender and elongate species, and juveniles may be more active than adults (Coker et al. 1921). Some sources have questioned whether large specimens of heavy-shelled species could even rebury themselves if dislodged (e.g., when collected by musselers, but subsequently released). However, observations of specimens placed in laboratory aquaria filled with moderately-sized gravel indicated southern mapleleafs over 102 mm in shell length and threeridges over 127 mm in shell length were quite mobile and readily burrowed into the substrate [RGH]. Naturally, animals released in the field over inhospitable substrates may fare less well. Yellow sandshell has been reported to follow flood waters onto inundated areas, then return as water levels recede (Coker et al. 1921). Other species have been observed to move from shorelines to deeper waters during periods of high wave activity (Headlee and Simonton 1904).

Mussels are normally imbedded in the bottom about half to three-quarters of their length (Coker 1919). Many mussels show algal growth or other discoloration on exposed areas indicating how deeply they were buried. Some species like paper pondshell may lay on the bottom or bury slightly. Others like yellow sandshell are frequently found completely imbedded in the bottom. Southern mapleleafs taken in Nasworthy Reservoir, Tom Green County, were frequently found on the surface of the substrate or buried about three-quarters their length; however, other specimens taken in the heated discharge canal of a power plant on the reservoir were typically found almost completely buried (perhaps in an effort to avoid excessive water temperatures) [RGH].

Imlay (1972) reported apparent greater adaptability to natural displacement than to artificial disturbance; mussels moved by hand sometimes failed to bury and resume normal positions, but those displaced by water currents or natural factors were more likely to continue normal behavior. Commercial harvest regulations which allow hand picking by a diver or harvest by brail and crowfoot may contribute to mussel mortality. Brails do contribute to high mortality rates among mussels taken and subsequently released but are also very inefficient; therefore most mussels are not disturbed and should not experience high mortality. Conversely, a diver can be very efficient at locating mussels within a given area, but if Imlay is correct, substantial mortalities may occur among specimens disturbed or removed from the substrate and then subsequently released.

Over-wintering and Drought Tolerance:

Freshwater mussels of some species may move to deeper waters with approaching cold weather, often leaving trails on the substrate indicating their direction of travel (Evermann and Clark 1918). Generally, little is known about over-wintering habits of most mussels (Coker et al. 1921). Brailers often report mussels cease "biting" during colder periods (Coker 1919; Coker et al. 1921), and others indicate mussels may not migrate or bury themselves deeper with the onset of winter, but become "benumbed" (Coker et al. 1921). However, Evermann and Clark (1918) noted mussels were not altogether inactive during winter, and discussed observing tracks in the substrate through clear ice. Several Texas musselers indicated on survey questionnaires (Howells 1993) that mussel die-offs had occurred on occasions during extremely cold winters. Similarly, personnel at Inks Lake State Park, Llano and Burnet counties, reported mussel deaths every second year in Inks Lake when water levels were dropped 3 m during December.

Pondhorns and threeridges have demonstrated a remarkable ability to dig in deeply during drought (Coker 1919). Pondhorns have reportedly been plowed up alive in a pond bottom three months after it had gone dry (Coker 1919). Strecker (1931) indicated both pondhorn and round pearlshell (Glebula rotundata) could survive for months on dry land. Read and Oliver (1953) found Texas lilliputs (Toxolasma texasensis) lying alive on a dry stream bed two months after dewatering.

Other mussel species are decidedly intolerant of dewatering. Shells of yellow sandshell may not close completely, so rapid dehydration and death may occur when specimens are not submerged (Coker 1919). Additionally, Strecker (1931) reported fragile papershell would perish in water less than 152.4 mm deep. Paper pondshells taken during surveys by TPWD often sealed poorly when closed, and leaked water and took air into the

mantle cavity when moved to transport containers so that they floated when returned to the water, thus indicating a similar lack of tolerance to dewatering.

Read and Oliver (1953) reported, heavy-shelled species of mussels left shallow areas with increasing summer temperatures, but thin-shelled floaters moved vertically deeper into the sediments in a shallow stream near Dallas. Metcalf (1983) suggested that drought lasting several years might produce even greater decimation among mussel populations and perhaps to their fish hosts, than short-term droughts, and further, that droughts may actually extirpate some species from certain streams.

Responses to Stimuli:

Mussels are sensitive to touch, vibration, and light (Coker et al. 1921). Coker et al. (1921) described mussels in bright light retracting their siphons when a shadow passed over. They indicated aquarium-held specimens would be extended in lighted condition, but would close when the tank was covered with a black cloth. Imlay (1969) reported small changes in light levels would cause mussels to close, touch may cause a fast-close response, slight vibrations may cause opening, and water changes may prompt either opening or closing. Bleufers held in laboratory tanks were exceptionally aware of even quick passage of an object between the artificial-light source and the holding tank and closed quickly in response to a fast-moving shadow [RGH].

Parasites, Diseases, Predators, Abnormalities

Water mites are often the most common mussel parasites (Coker et al. 1921). Mites may feed on mussel tissues and fluids, and lay eggs in their flesh; mite eggs may actually become covered with nacre and produce pearls (Coker 1919). Vidrine (1980) identified 53 species of mites among approximately 15,000 mussels of 175 species examined in North America, including the genera Unionicola, Najadicola, and Atacella. Some mites were rather host specific; others were generalists. Calnan (1976) found five species of water mites (Unionicola tupara, U. abnormipes, U. fossulata, U. aculeata, and U. formosa) as well as three additional unidentified species in unionids in the Navasota River, Texas, and Flook and Ubelaker (1972) reported mites of the genus Unionicola in freshwater mussels in Denton County, Texas. Southern mapleleafs and giant floater in central Texas, for example, are often among the most frequent water mite hosts. Unionid mussels from Nasworthy Reservoir on the Concho River commonly have a small black species, and some individuals from Lake Gonzales on the Guadalupe River often have another species which is round and mottled, black laterally, and red dorsally. Neves (1987) indicated pathogenesis from water mite infestations was rare.

Leeches sometimes occur in the mantle cavity where they feed on mucus; trematodes or flukes, ascarid and distomid worms, the oligochaete Chaetogaster limnaei (more frequently found in snails), and varieties of protozoans can occur in unionid mussels (Coker et al. 1921). Calnan (1976) reported three trematodes from unionids in the Navasota River, Texas, including Cotylaspsis insignis, Aspidogaster conchicola, and Cotylogasteroides barrowi, as well as Cercaria amblemaea, bucephaloid cercaria (possibly Cercaria scioti), and an allocreadid metacercaria (possibly Polylekithum ictaluri). Among freshwater mussels in Denton County, Flook and Ubelaker (1972) found Aspidogaster conchicola, Cotylapsis insignis, Bucephalus elegans, and rhopalocercous cercariae. Algae are frequently found on exposed portions of the shell, but they are not parasitic in nature.

A number of diseases apparently impact unionid populations; however, these are generally ill-defined and poorly known. Neves (1987) discussed mussel diseases and indicated before as recently as 1985, only two, tumor-like pathogenic conditions were known. Some reports have referred to apparent deaths from "agent X" (Bates 1987) or identified bacteria found as "yellow or non-yellow colonies" (Kern 1987).

Predators on freshwater mussels include mink (Mustela vison), muskrats (Ondatra zibethicus), raccoons (Procyon lotor; Fig. 8), some water birds, turtles, fishes, hogs, and, of course man (Coker et al. 1921). Muskrats in particular are noted for creating piles of mussel shells at favorite feeding sites, and more than one distributional study has used muskrat shell piles as an indicator of mussel species present in their study area. Among the turtles, the map turtles (Graptemys spp.) often prey extensively on small shellfishes, including small mussels. Several map turtle species occur in Texas, and two are endemic. Fishes which feed heavily on mussels are also often utilized as hosts by their glochidia as well (see discussion under Glochidia and Parasitism).

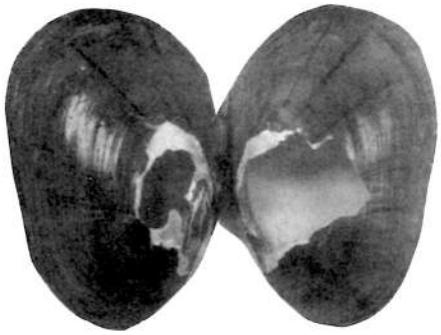


Figure 8. A Louisiana fatmucket (Lampsilis hydiana) killed by a raccoon (Procyon lotor).

A variety of malformities are regularly noted among unionid mussels. Coker et al. (1921) reported some parasites may cause staining or discoloration of the nacre, and may be responsible for the steely or leaden markings internally on the shell. They further noted that yellow and brown spots found both on the surface and deep within the nacre were a nitrogen-based organic material bonded to the calcium carbonate layers. Metallic gold-colored spots in the nacre of washboards may also be caused by infections (Oesch 1984) and similar gold-colored markings have also been observed in other species like threeridge, yellow sandshell, and pistolgrip [RGH].

Distortions of typical shell shape such as abbreviated margins, thickened or rolled-back edges, and gaping areas between valves (Fig. 9) may also be caused by parasites which interfere with shell growth at the site of encystment while allowing continued growth in adjacent areas (Coker et al. 1921).

Mechanical damage to unionid shells is frequently observed as well. Worn areas on the epidermis are common in some species, especially in certain abrasive habitats. Mussel-eating mammals sometime bite and penetrate a shell too large to be ultimately opened and killed; survivors may display major healed dents or cracks, often on both valves. Similarly, some shells show damage to a single valve resulting from some mechanical injury.

ECOLOGY

Abundance

Freshwater mussel abundance in North America in general, and in Texas specifically, has been poorly studied. Indeed, losses due to overharvest, pollution, and habitat alteration probably impacted many populations long before science directed significant attention to unionids. Mussel populations were sometimes dramatically altered before they were studied. Declines in the 20th century have been attributed to waterway modifications, changes in stream beds, commercial mussel fisheries, water quality deterioration, sedimentation, agricultural runoff, industrial pollution, commercial barge activity, and competition with introduced Asian clams (Havlik and Marking 1987). Neck (1982a) indicated land clearing, urban development, and ground-water withdrawal were major problems associated with rapidly changing water levels and velocities, and that water pollution from municipal, agricultural, and industrial sources generally reduce benthic community diversity, including that of unionids.

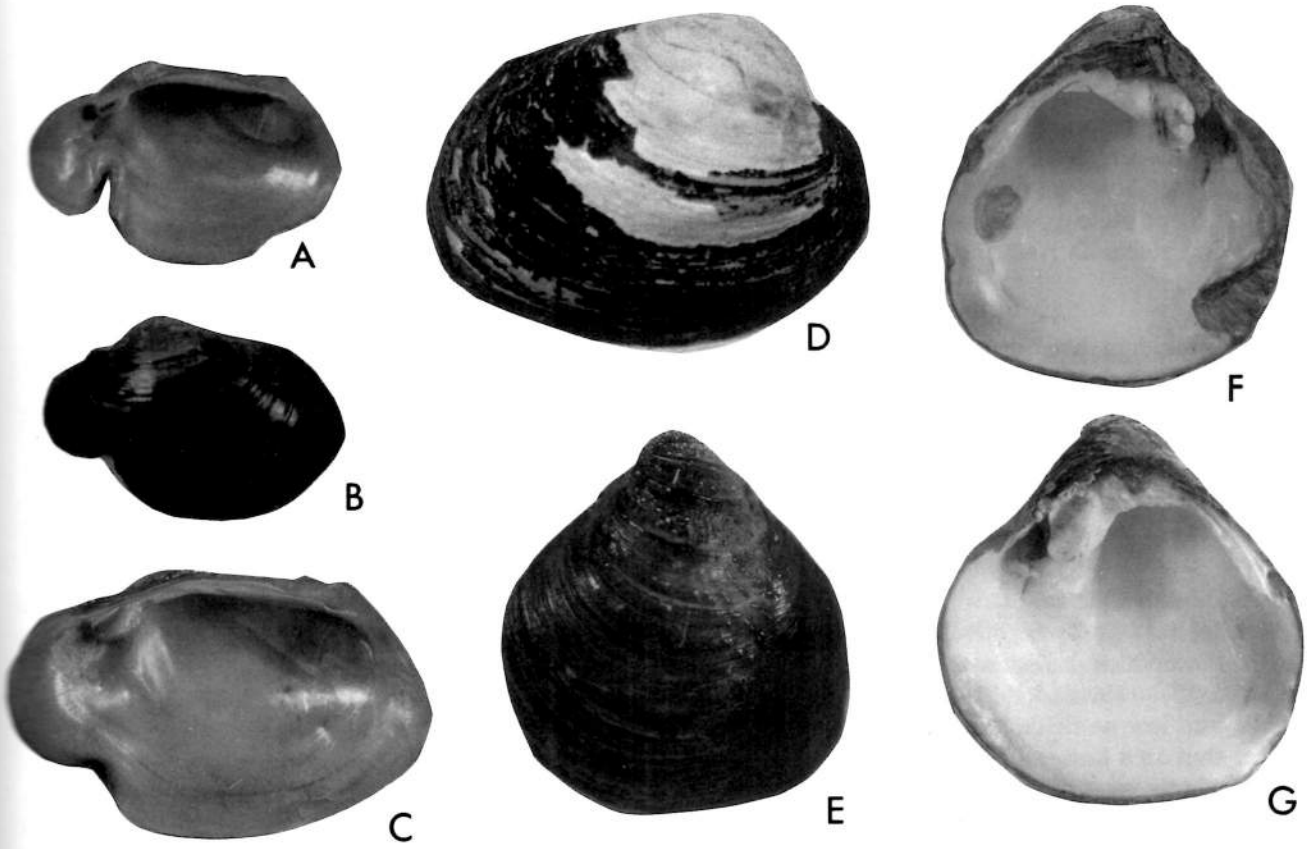


Figure 9. Freshwater mussel shell deformities. A-C. Tampico pearlymussel (Cyrtonaias tampicoensis) valves with deformities on the ventral edge of the shell. D. Tampico pearlymussel valve atypically shortened posteriorly. E-G. Southern mapleleaf (Quadrula apiculata) dramatically shortened posteriorly with external shell surface turned and growing inward.

In Texas, detailed studies of mussel abundance have been all but non-existent. However, in 1992 TPWD biologists began preliminary population studies of mussels at selected locations across the state, with plans to intensify efforts in subsequent years. Unfortunately, estimates of abundance prior to the onset of commercial harvest, and losses due to pollution and environmental alteration, are largely unavailable. Strecker (1931) reported mussels from areas of the Trinity River near Dallas, but 21 years later Read and Oliver (1953) found no live unionids in some of these same locations, apparently reflecting development and pollution problems in the system at and downstream from Dallas.

Neck (1982a) noted reservoir construction was probably the most significant factor influencing mussel populations. This may be especially noteworthy in Texas where only a single natural lake (Caddo Lake) existed prior to construction of reservoir dams. Impounding flowing waters to form reservoirs may alter mussel population structure and abundance (Neck 1982a). Species requiring flowing waters may also be excluded from reservoirs; however, reservoirs may increase suitable habitat over preimpoundment stream habitats, create deep-silted areas favorable to some species but excluding others, and may form deep, anoxic waters that may exclude all unionids. However, Neck (1989a) found no local unionids were extirpated by the construction of Arrowhead Reservoir on the Wichita River in northcentral Texas.

Mussels are not typically randomly distributed within a water body. They may be scattered and sporadic in some areas, absent in others, or occur in relatively dense beds. Clark and Wilson (1912) reported densities of 81 specimens of eight species in a 1-m^2 sample, and 66 specimens of 10 species in 0.4 m^2. Coker et al. (1921) found

52 specimens of six species in a 1.7-m^2 area; they indicated greater densities in culture situations with examples over 2,300/m^2.

Factors Affecting Reproduction

Reservoir construction may alter water temperature and chemistry, and, in turn, may impact successful spawning of mussels (Isom 1971; Cvancara and Freeman 1978). Stresses associated with disturbance during mussel harvest activities may cause some females to prematurely empty their brood pouches and discharge embryos or glochidia. Some state management agencies do not allow harvest during seasons when washboards are spawning and carrying glochidia (fall and winter) in an effort to maximize successful reproduction of this commercially valuable species.

Dam building activity which blocks migratory fishes or changes fish communities can impact mussel communities that depend on these fishes as glochidial hosts. Eddy and Underhill (1974) discussed how dam construction, which blocked runs of skipjack herring into Lake Pepin on the Mississippi River, ultimately led to the demise of mussels above the dam. Similarly, fish management practices can potentially impact mussel populations when the status of host fishes is changed.

Factors Affecting Natality, Recruitment, and Mortality

Contaminants in the environment appear to be causes not only of immediate mussel die offs, but may have more subtle, but equally negative, impacts on mussel survival as well. Mussels may be destroyed directly through the toxic effects of environmental contaminants, or indirectly by elimination of essential food supplies (Havlik and Marking 1987). Havlik (1987) reported high concentrations of some pesticides could cause lasting closure of glochidia and low pesticide levels for longer periods could cause gaping; both ultimately prevent glochidia from snapping shut on a host, and thus interrupt the life cycle. Havlik (1987) also noted some young fish parasitized by mussel glochidia were themselves more susceptible to pollutants like oil, toluene, and naphthalene. Heavy metals have been found more toxic to mussels than to certain fishes (Chin and Chow 1978). Dieldrin and DDT residues have been shown highest in reproductive and digestive tissues (Bedford and Zabik 1973). Ammonia may be lethal to mussels even when dissolved oxygen concentrations are not low enough to indicate environmental problems (Horne and McIntosh 1979). Sensitivity to some toxins appears greater in younger life stages (Maki et al. 1975). Havlik and Marking (1987) provided a review of the literature on contaminant impact on mussels.

Shira (1913) indicated salt water and wastes from oil and gas wells in the Caddo Lake area had destroyed many mussel beds. Horne and McIntosh (1979) discussed the relationship of sewage effluent in the Blanco River to mussel abundance. Several musselers responding to a 1992 TPWD questionnaire survey (Howells 1993) reported mussel kills associated with pollution in rivers and reservoirs, and one implicated illegal dumping of toxic materials as responsible for mussel losses in one reservoir.

Interestingly, most fish toxicants do not appear to be a serious threat to mussel survival (Havlik and Marking 1987; Marking and Chandler 1978). Sampling fish communities with poisons like rotenone is a common practice in fishery management and research; however, dosages used to kill fish in standard sampling appear to be tolerated by most mussels (Havlik and Marking 1987).

Siltation, often associated with poor land-use practices, can have a significant impact on mussel survival. Marking and Bills (1980) indicated silt coverings greater than 18 cm in depth were needed to prevent some species from emerging after being covered, but found silt depths of 10 cm could block up to 50% of other mussel species from reaching the surface; they also noted mussels positioned horizontally when covered had greater difficulty emerging than those oriented in a normal vertical position.

Importance in the Ecosystem

In the overall, big picture of environmental awareness, freshwater mussels unfortunately lack appealing features. Many species are not even especially aesthetically attractive. Generally, their existence is not supported by sport hunters or anglers. Indeed, most are rather difficult to even observe. To the disadvantage of the group, it is difficult to generate public, and even sometimes scientific, concern for the future of animals which can be

otherwise so cryptic. None the less, mussels do have many functions, both in the aquatic ecosystem and as species supporting commercial and sport fisheries. Neck (1982a) discussed their importance in removing environmental pollutants, suspended sediments, and small organisms (a living filter), providing shell surfaces on which other organisms flourish, and as a source of food for some fish, birds, and mammals, including several economically significant fur-bearers.

Freshwater mussels are reliable indicators of pollution (Havlik and Marking 1987). They have proven useful in monitoring pesticide levels that would otherwise be undetectable by concentrating otherwise low levels (Bedford et al. 1968). They can be an important bioassay organism (Neck 1982a).

EXPLOITATION AND COMMERCIAL IMPORTANCE

Prehistorical and Historical Harvest

Use of freshwater mussels by Native Americans stretches well back before recorded times. Evidence of utilization of shells, pearls, and meat ranges from the Caddos of eastern Texas to early inhabitants of the Rio Grande and Concho River (discussion in Neck 1982a). Shells were used both ornamentally and as tools (Murray 1982; Chandler and Kumpe 1992; Lintz 1992). Pearls also served ornamental purposes, and were sometimes placed with the dead at burial sites (Kunz 1897). Meat was undoubtedly eaten and probably served as an important dietary component at certain times (Neck 1982a); however, Parmalee and Klippel (1974) provided evidence that mussel nutritional components were too low to have represented the mainstay suggested by some. Extensive shell mounds and large quantities of pearls reported from archaeological digs and historical records (Kunz 1897) indicate both extensive and long-term harvest. None the less, early use of unionid mussels by Native Americans apparently had no significant impact on populations of these mollusks in Texas waters, or elsewhere.

Early European explorers were sometimes quick to take note of the pearls associated with many Indian cultures. Spanish adventurers in eastern Texas reportedly relieved local residents of hundreds of pounds or bushels of pearls (Kunz 1897), for subsequent shipment to Mexico or Spain. Large numbers of pearls were often removed from grave sites, and one report laments pearl disintegration due to contact with decomposing corpses (Kunz 1897). Along the Concho River, the Spanish engaged in active pearling operations to harvest local mussels, and although harvest rates were sufficient to actually depopulate certain areas, success at locating pearls was apparently minimal (Williams 1990).

Following early Spanish interest in Texas mussels, unionids seem to have received little or no attention, at least in historical reports. However, a questionnaire survey in 1895 by the U.S. Fish Commission, which sought to ascertain the status of pearl fisheries, solicited five responses from Texas. Among these, one indicated mussel populations were extirpated and two listed them as depleted (Kunz 1897). The first major attention to Texas mussels probably came in 1909 when a Japanese immigrant took two gem-quality pearls from mussels in Caddo Lake. This discovery provoked a subsequent pearl rush there and in several nearby waters which ended several years later when dam construction downstream increased water levels in Caddo Lake and made continued harvest impractical (Shira 1913). As many as 400 musselers were reported working the lake in a single year, and discarded shell piles sometimes contained hundred of tons of shells (Shira 1913). Other largely-undocumented mussel fisheries also occurred in subsequent years. Elderly residents along the Llano River still recall musselers traveling the river by wagon to harvest shells and pearls [RGH] and Strecker (1931) reported mussel population decimation in the area. A small shell-button industry existed for a time on the Rio Grande at Mercedes (Neck 1982a), and soldiers apparently harvested shell for buttons at Fort Brown, Cameron County, earlier in this century (Neck 1990b). Otherwise most Texas mussel populations were spared the extensive overharvesting that plagued much of the Mississippi Valley. Neck (1982a) indicated high cost of transportation and high local oil field wages in northeastern Texas contributed to discouraging harvest for the button-shell industry in the Caddo Lake area; these same reasons likely applied to other Texas waters as well.

Current Harvest in Texas

Although mussel-harvest permits or licenses have been required in Texas for many decades (Neck 1982a; Howells 1993), no significant effort to monitor the fishery was implemented until early 1992 when TPWD surveyed

mussel license holders (Howells 1993). Harvest for pearls, shell, and sometimes food no doubt occurred in Texas prior to the 1970s, but annual license sales from 1963 through 1977 usually only ranged from zero to three per year (Neck 1982a; Howells 1993); yearly harvest was likely minimal. However, in 1977 license sales jumped to over 200, and 400-500 in subsequent years (Neck 1982a; Howells 1993). Curiously, mussel license sales have proven to be very responsive to published magazine articles and television programs with dramatic spikes in sales invariably following publication of newspaper and magazine articles on pearls and pearling (e.g., Pinkard 1979; Kennedy 1985a,b; Ward 1985; Blakely 1988; Williams 1990; Portwood 1992). But again, harvest levels, though unmonitored, were likely relatively low during much of this period compared to 1990-92 harvest.

In the 1970s and 1980s, the complexion of American mussel shell harvest changed with development of and increasing demand by the cultured pearl industry for American mussel shell. Many Mississippi Valley populations never fully recovered from extensive overharvest earlier in the century, and shellers actively sought new waters. During drought years of 1978 and 1980 and with the arrival of a major shell-buying company, mussel license sales increased (Neck 1982a). In the late 1980s, Texas was rediscovered and harvest levels again skyrocketed. By 1990 and 1991, commercial shellers were coming to Texas from as far away as Oregon, Tennessee, and Illinois (Howells 1993). Local mussel populations which had seen years without major harvest were abruptly experiencing heavy harvest pressure.

Collection Methods, Gear, and Regulations

Across North America a wide variety of harvest methods and gears have been employed in mussel fisheries (Coker 1919). Data resulting from mussel license holder survey early in 1992 indicated that most musselers in Texas employed simple approaches to harvest rather than resorting to exotic gear and heavy equipment (Howells 1993). The TPWD Code (state law) provided for a "Clam, Mussel, and Naiad License" as well as an additional permit required for the use of dredges; however, relatively few dredge permits have been sold on an annual basis. Other harvest gears were not originally prohibited under the law, yet few individuals employed other methods here.

Most musselers either wade or dive (either free diving or with some underwater breathing device) and hand pick individual mussels, or occasionally use a hand-held rake. Use of brail and crowfoot bars and hooks is all but nonexistent, and although a small number of dredge permits are sold annually, general limits to success with dredging has historically restricted gear of this type. However, a report was received [RGH] from residents in Guadalupe County who described nonresident commercial musselers using a dragline-type dredging operation to literally excavate washboard beds in area reservoirs. Diving to harvest mussels has been labeled by some as the greatest threat to commercially valuable mussels (Fuller 1974). However, diving potentially has far less environmental impact than dredges, which may damage the substrate. Brails (Fig. 10) may pass lightly over the substrate doing little environmental damage; however, brailers may remove obstructions to eliminate gear fouling. Both gears may injure or kill subsized animals. Regulations revised and effective September 1992 and modified in 1993 allow only harvest by hand in state waters, with or without diving gear.

Although some full- and part-time commercial musselers use SCUBA, many use air pump and hose rigs (hooka pumps) mounted in a boat or towed in a float. There is little regulation in Texas of such equipment or diver training; some even use home-made devices. Subsequently, human injuries and death have been reported. Many amateur musselers wade or snorkel shallow waters, or float in inner tubes, and often locate mussels with their feet (toe digging).

TPWD regulations 1992-1993 include the following:

- Collection by hand only,
- Limited harvest under a fishing license (other harvest under a mussel license),
- Harvest during daylight hours only,
- Weekend bag limits of not more than 75 pounds on or within 500 yards of public waters,
- Minimum harvest size (minimum size that will pass through a ring with the specified inside diameter):
    - Washboards (Megalonaias nervosa) - 4.0 inches,
    - Threeridges and roundlakes (Amblema spp.) - 2.75 inches,
    - Mapleleafs and pimplebacks (Quadrula spp.) - 2.75 inches,
    - Tampico pearlymussels (Cyrtonaias tampicoensis) -2.75 inches,

- Bleufer (Potamilus purpuratus) - 2.75 inches,
- All other species - 2.5 inches,

- No-harvest mussel sanctuaries at 28 locations around the state.

Note the minimum 2.5-inch ring size (i.e., 63.5 mm in mussel shell height) serves to protect many species which never grow large enough to be harvested, or do so only rarely. Additionally, these regulations on harvesting mussels are subject to periodic review and modification. The most recent regulations should be obtained from TPWD before harvesting mussels in Texas.

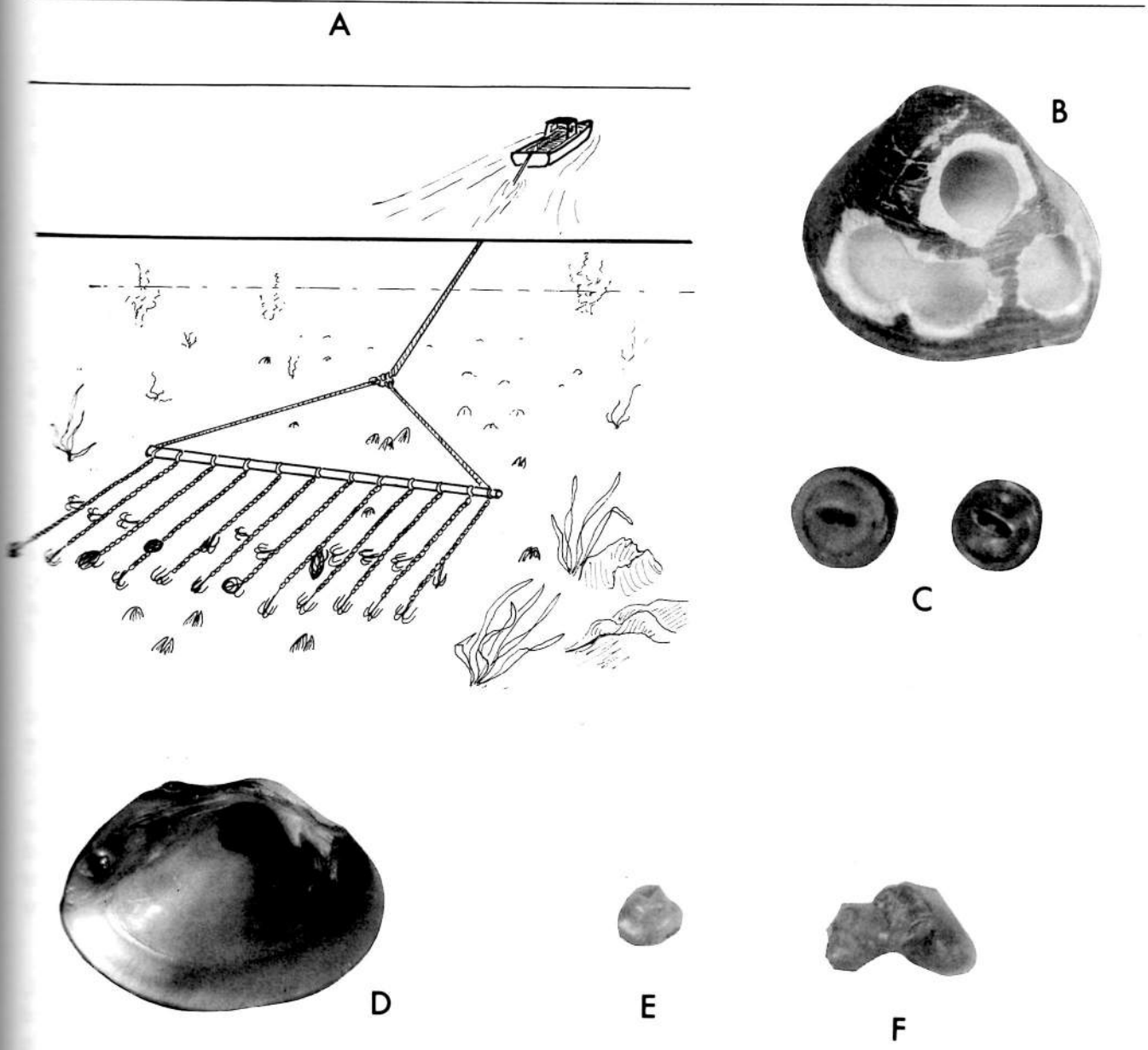


Figure 10. A. Brail being pulled behind a boat to gather mussels. B. Freshwater mussel shell drilled in the production of shell buttons. C. Buttons made from freshwater mussel shells. D. Tampico pearlymussel (Cyrtonaias tampicoensis) with a pearl imbedded in the shell. E-F. Freshwater pearls; the slightly-irregular 10-mm specimen (E) was produced by a Tampico pearlymussel and the 19-mm strongly-baroque example (F) was found in a washboard (Megalonaias nervosa).

Uses

Shells:

Although there were a number of minor and short-lived button manufacturing efforts in the early and mid-1800s, the first successful business to produce button from mussel shells (Fig. 10) began in the last decade of the century (Coker 1919). A German immigrant and button-factory worker, J.F. Boepple, came to the U.S. in 1887 in response to shells sent to his father from America and established the first successful button factory in Muscatine, Iowa, in 1891 (Coker 1919). Intense harvest of mussel stocks soon prompted concern for the continued survival of this valuable natural resource, and by 1894 the U.S. Fish Commission turned attention to mussels and the mussel fishery (Jones 1950). The Commission ultimately built a research station at Fairport, Iowa, to study mussels, the mussel fisheries, and methods of culture; scientists like Lefevre, Curtis, Shira, Clark, Howard, and others produced numerous manuscripts (Jones 1950) still in use today. The shell button industry continued into the present century and ultimately gave way to depleted beds and the development of plastic buttons. Although one commercial and other minor button making operation developed in Texas (Neck 1990b), apparently no major button industries have existed here for many years.

There has been a sporadic and relatively limited demand for mussel shell for curios, mother-of-pearl-inlay products (Neck 1982a), and occasionally for polished shell chips (Mathiak 1974). However, a questionnaire review of both sport and commercial musselers in Texas in 1992 found none of the respondents indicating harvest for these purposes (Howells 1993).

The most significant reason for mussel harvest has been for white-nacred species whose shells are sold for use in the cultured pearl industry (Neck 1982a; Howells 1993). Estimates from a survey of musselers in Texas suggest between 600 and 1,200 tons were taken here in 1991 (Howells 1993). Some musselers even indicated the price paid for shell was so high they did not examine harvested specimens for pearls (Howells 1993).

Pearls:

Certainly few aspects of bivalve biology or morphology generate as much public reaction and interest as do the pearls they sometimes produce. Pearls are not only generated by marine oysters and other saltwater bivalves, but are also produced by freshwater unionid mussels as well. Indeed, pearls were regularly harvested from European freshwater mussels in the middle ages (Muus 1967) and by American Indians long before the New World was discovered (Kunz 1897).

The first American pearl rush occurred in 1857 in Patterson, New Jersey, when a pearl worth $2,500 (then) was discovered; not long thereafter, streams in the area were reportedly "cleaned out" (Kunz 1897). Pearling gradually extended westward and sometime after 1880, Texas, Tennessee, and Kentucky became major pearl-producing areas (Kunz 1897). A pearl-harvest frenzy hit Arkansas and Oklahoma in 1894-1895 (Kunz 1897). Although many cite a 1909 pearl rush at Caddo Lake and adjacent waters in Texas as the first pearl rush in Texas (Shira 1913), Kunz (1897) conducted a survey of American pearl fisheries for the U.S. Bureau of Fisheries and obtained information from several respondents in Texas who, in 1893-1894, rated mussel populations in some streams as depleted or reduced. Similarly, Strecker (1931) indicated several decades later that some areas of the Llano River of central Texas had been decimated by pearlers.

Many unionid mussels produce pearls; however, some do so only very rarely, and others produce small, brittle, or hollow pearls which crack upon drying and are of no value. Among those mussels in Texas waters listed by Kunz (1897) which occasionally produce gem-quality pearls are: threeridge, western pimpleback (Quadrula mortoni), pocketbook (Lampsilis ovata = L. cardium?), white heelsplitter, and washboard. Other species listed by Shira (1913) included bankclimber and pistolgrip. Bleufer may also produce pearls (Oesch 1984), though many pearl hunters in Texas ignore it as unproductive. Local musselers have reported pearls in southern mapleleaf but indicate such occurrences are quite rare. Perhaps the most significant pearl producers in Texas, Tampico pearlymussel is the source of "Concho River pearls" which were well known to local Indians and later by Spanish adventurers. This species supports a pearl fishery and associated jewelry business today (Pinkard 1979; Kennedy 1985 a,b; Williams 1990).

The Texas pearl fishery has never been formally monitored. One jeweler in the San Angelo area reported purchasing 500-1,200 per summer (Pinkard 1979) and 1,800-2,000 per year (Williams 1990), but with reports of only 210 purchased in 1990 following a destructive freeze in the mid-1980s (Williams 1990). Pearls 10-13 mm in diameter are considered large in Texas; 14-15-mm specimens are considered exceptional.

The number of pearls found in a single mussel and the frequency of occurrence is poorly documented, and apparently quite variable. Sometimes more than 100 small pearls may occur in one specimen (Sweaney and Latendresse 1984). Among Tampico pearlymussels, it has been reported that one in 10 produces a pearl, one in 10 of those will be of some value, and only one in 1,000 will be of gem quality (Kennedy 1985a,b). On one occasion, TPWD biologists watched a musseler open 12 Tampico pearlymussels and recover two large pearls and a variety of smaller ones. Shira (1913) reported that among 793,393 Caddo Lake mussels (bank climbers, washboards, and pistolgrips predominantly), only 53 pearls were produced with a value of $1,405 (then). Kunz (1897) received responses to a survey indicating frequency of pearl occurrences ranging from one in 20 to one in 100,000.

Pearls were found in some mussels dissected during TPWD mussel spawning season studies (1992-1993), but most contained relatively few pearls. Examples of the frequency of occurrence of pearls among dissected specimens were:

Species	Number Examined	Number Pearls	Frequency (%)
Washboard	68	1	1.47
Bleufer	31	0	0
Tampico pearlymussel	329	13	3.95
Southern mapleleaf	361	0	0
Threeridge	121	0	0
Western pimpleback	94	0	0

This count does not include "shell pearls" attached to the shell (Fig. 10) or other interior shell imperfections. Such shell imperfections were most common in Tampico pearlymussel, less frequent in washboard, and relatively uncommon in the remaining species. Among the pearls found in Tampico pearlymussels, only one was larger than 10 mm in diameter, most were only one to three mm in diameter (several were smaller), and none were of exceptional quality.

Pearls are generated by the mantle in response to an irritation caused by accident, disease, parasites, or foreign bodies (Kunz 1897); additionally, bits of shell, debris, possibly fish scales, parasite eggs, and perhaps even loose bits of mantle may prompt pearl formation (Sweaney and Latendresse 1984). Sometimes small fishes or crustaceans entering the mussel may become covered with nacre as well (Kunz 1897). Additionally, pieces of mussel shell, especially lateral and pseudocardinal teeth and fragments from mechanical damage, may also be nacred-over to form pearls. Some pearl culturists dismiss the classical sand grain theory of pearl formation (Sweaney and Latendresse 1984). Deformed or damaged shells are believed by many pearlers to contain large pearls or at least have an increased probability of producing a pearl; this theory is not without some basis in logic.

Kunz (1897) recognized three basic types of pearls. Free pearls occur in the soft tissues and are often round, pear-shaped, or irregular (Fig. 10); they may occur singly or in groups. Blister or half-pearls (Fig. 10) develop between the mantle and the shell, and are typically flat or nearly so on one side. Hinge pearls develop from broken shell teeth or other parts of the hinge and are irregular in shape; long, spatulate pearls often form from nacred lateral teeth that have been sheared off. One or more pearls may grow together or to the shell. The term baroque is applied to oddly- or irregularly-shaped pearls. Most natural pearls are baroques; truly spherical pearls are very rare, often less than 0.01% of the total. Pearls may occur almost anywhere within the shell. Tampico pearlymussels are particularly noted for having pearls located loosely in the posterio-ventral area so that when the mussel is opened, the pearl readily falls out. More than one amateur pearler has lost valuable, gem-quality pearls by opening mussels over the water.

Natural pearls contain calcium carbonate in the form of aragonite (82-86%), conchiolin (10-14%), and water (2-4%) in addition to a variety of trace elements (Sweaney and Latendresse 1984). Pearls occur in a wide variety of colors. Although pearls can disintegrate under unfavorable environmental conditions (Kunz 1897), dead

mussel shells and their surroundings should be examined when located in the field. Pearls are occasionally found in the mud that sometimes occurs between the valves of a dead animal whose soft tissues have disintegrated, or are sometimes located on the substrate immediately below a pair of valves. Sometimes pearls recovered from animals that expired long before discovery can be buffed or polished to improve appearance.

Meat:

Neck (1982a) indicated meat accumulated by the pearl-culture industry was sold for pet food. Musselers responding to a questionnaire in 1992 indicated some meat was used for trot-line bait, and some was sold for this purpose; about 40% of the respondents indicated using mussel meat in some way, but the rest indicated it was simply discarded (Howells 1993). Several respondents indicated they harvested mussels specifically for human consumption (Howells 1993). Although published literature has discussed techniques for cooking local mussels (Bigony 1979), harvest and consumption of mussel meat presents several problems. First, unionids not only potentially contain environmental contaminants, but also can actually concentrate them (see summary in Havlik and Marking 1987). Consumption of mussels could literally be medically hazardous. Secondly, Texas Department of Health regulations only permit harvest of bivalves for human consumption from waters certified as safe. Freshwater areas are not examined by that department; therefore, by default, they are not certified and not considered safe. Mussels from some localities might actually be safe to consume, but in view of the potential medical risks, eating freshwater mussels is not advised.

Live Pearl-culture Mussels:

At present in North America, production of cultured pearls on a commercial basis using freshwater mussels occurs only in Tennessee where harvest of otherwise sublegal-size mussels is permitted for subsequent use as nucleus recipients (R.M. Todd, Tennessee Wildlife Resources Agency; pers. comm.). Several Texas residents have reported experimenting with pearl culture locally using Tampico pearlymussels, and some have indicated initial successes. To date, some live mussels have been taken from state waters for experimental culture purposes, but the number harvested for this purpose is almost certainly minimal compared to numbers taken for shell and pearls. Although some states may allow pearl culture in their public waters, such pearl culture in the public waters of Texas has legal problems because one cannot legally cage-or fence-off areas of public waters.

Smaller, immature unionids grow faster and subsequently produce cultured pearls faster than do larger, sexually-mature specimens; however, larger individuals can be implanted with more pearl-forming nuclei. Ward (1985) indicated cultured pearl production time in Tennessee with washboard mussels was about 2-3 years, with a similar period of about three years in Lake Biwa, Japan, in pearl-culture mussels there. Representatives of the Japanese pearl-culture industry have more recently noted that cultured pearl production time is currently averaging about 1.5 years in Japan [RGH].

During implantation to produce a cultured pearl, a shell nucleus (North American unionid shell) and a small piece of mantle are implanted into a recipient bivalve (then said to be nucleated); with luck, a cultured pearl may be produced in 1.5-3 years (Ward 1985). Unfortunately, some implants are rejected, and on some occasions, the implanted bivalve may die. Sizes of implants vary from less than 8 mm to around 17-20 mm (Ward 1985). Implants in Japanese waters acquire about 0.2 mm of nacre every 6 months, with the best luster requiring 0.35 mm of nacre or more (Ward 1985).

BIOGEOGRAPHY IN TEXAS

Until European settlement and the construction of dams and impoundments, Texas was largely a region of rivers and streams. It had only a single natural lake, Caddo Lake on the Louisiana border. In the northern and eastern portions of the state, the Canadian, Red, Sulphur, and Cypress Bayou systems flow easterly to the Mississippi Basin. Other river systems are isolated drainage basins which flow directly to the Gulf of Mexico.

Roback et al. (1980) included most of Texas in the Western Gulf Coast Faunal Zone, except areas in the northern panhandle and northeastern Texas placed in the Interior Basin Faunal Zone. Neck (1982b) designated four primary subprovinces within the state: (A) Texoma including the Canadian, Red, Sulphur, and Cypress Bayou

rivers; (B) Sabine including the Sabine, Neches, Angelina, Trinity, and San Jacinto rivers; (C) central Texas including the Brazos, Colorado, Guadalupe, San Antonio, Lavaca, and Nueces rivers; and (D) Rio Grande including the Pecos and Devils rivers; with an additional subprovince in coastal areas. Texas counties are presented in Figure 11. Numbers given in parentheses below correspond to those on the map of Texas river systems (Fig. 12). Major river systems (summarized from Kirkley 1983) include:

Canadian River (1): flows west to east across the northern Panhandle, and is generally depauperate of mussel fauna. Strecker (1931) speculated it may contain only four or five species; Neck (1982b) indicated only a single species. Neck (1987b) discussed Asian clams in this system. Under subsequent species accounts herein, distribution reports of "all major systems" do not include the Canadian River, unless otherwise noted.

Red River (3): flows from New Mexico 322 km east across the Panhandle and 708 km along the Texas-Oklahoma border to Arkansas. Historically, this system supported limited mussel populations, at least along the main channel; however, some tributary streams support mussel populations, and construction of Lake Texoma appears to have increased suitable habitat and diversity (White and White 1977; Neck 1982a; Mather 1989). Valentine and Stansbery (1971) reported only paper pondshell, lilliput, pondhorn, and yellow sandshell occurring upstream of Lake Texoma. Neck (1989a) discussed unionids in Arrowhead Lake on the Wichita River (2) and Neck (1987b) reported on Asian clams in the upper reaches of this system.

Sulphur River (4): flows 121 km across northeastern Texas and into Arkansas where it joins with the Red River. Although modified by channelization in upstream areas, this river was intensely fished by commercial musselers in the late 1980s and early 1990s [RGH]. Shira (1913) briefly discussed mussels in this system.

Big Cypress Bayou (5): is a short system of northeastern Texas largely in Upshur, Camp, Cass, Marion, and Harrison counties which flows into Caddo Lake on the Louisiana border. Shira (1913) discussed the early pearl fishery in the area and Shafer et al. (1992) reported more recently on local mussels.

Sabine River (6): begins east of Dallas in northcentral Texas, flows to the Louisiana boarder, then south to the Gulf of Mexico. Upper stretches of this river have been intensely fished in recent years by commercial musselers [RGH]. Neck (1986a) reported on mussels in Lake Tawakoni.

Neches River (8): along with its tributary the Angelina River (7), flows south through eastern Texas piney-woods and hardwood bottom lands. Neither river has been reported by musselers as a major area of harvest recently. Vidrine (1990) discussed mussels in the Village Creek tributary, Hardin County, in a report on parasitic water mites.

Trinity River (9): originates from four forks which unite north of Dallas and flow 885 km southeasterly to Trinity Bay. Upriver areas have experienced pollution and water quality problems which have reportedly eliminated mussels in some areas (Strecker 1931; Read and Oliver 1953). Despite its length, the Trinity River has relatively limited access, and subsequently received limited attention from scientists and musselers alike. Read and Oliver (1953) briefly discussed mussels in Dallas area streams and Neck (1990a) reported on unionids in Lake Lewisville.

San Jacinto River (10): is a short system with east and west forks located north of Houston and flows south to Trinity Bay. During low water levels in the 1980s, reports reached TPWD of washboard and threeridge mussels stranded in dewatered areas.

Brazos River (11): runs 1,352 km from western Texas southeast to the Gulf of Mexico, and is the longest river between the Red River and Rio Grande. Both sport and commercial musselers report fishing stretches of this system. Littleton (1979) reported on unionids in the Navasota River (13).

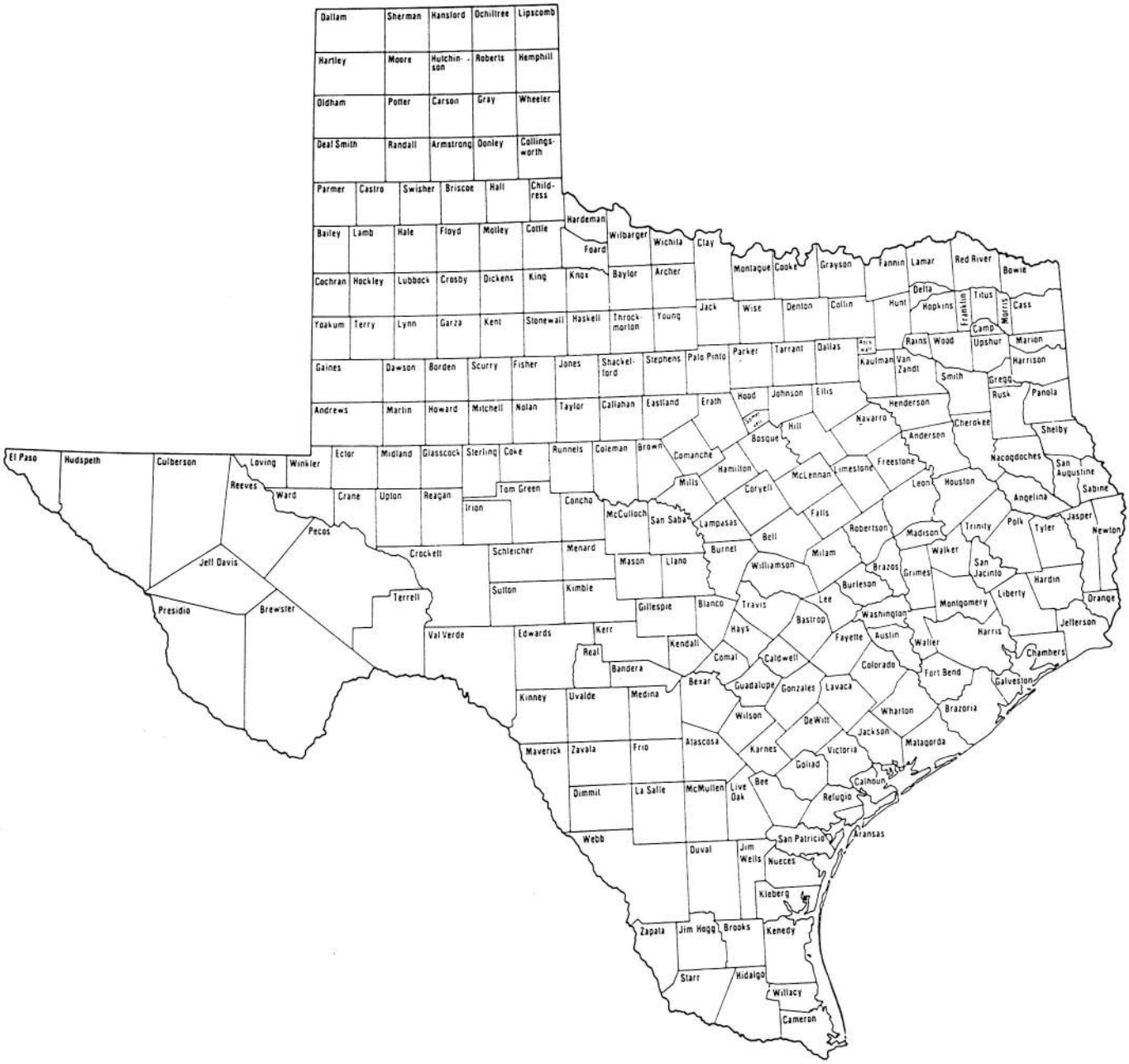
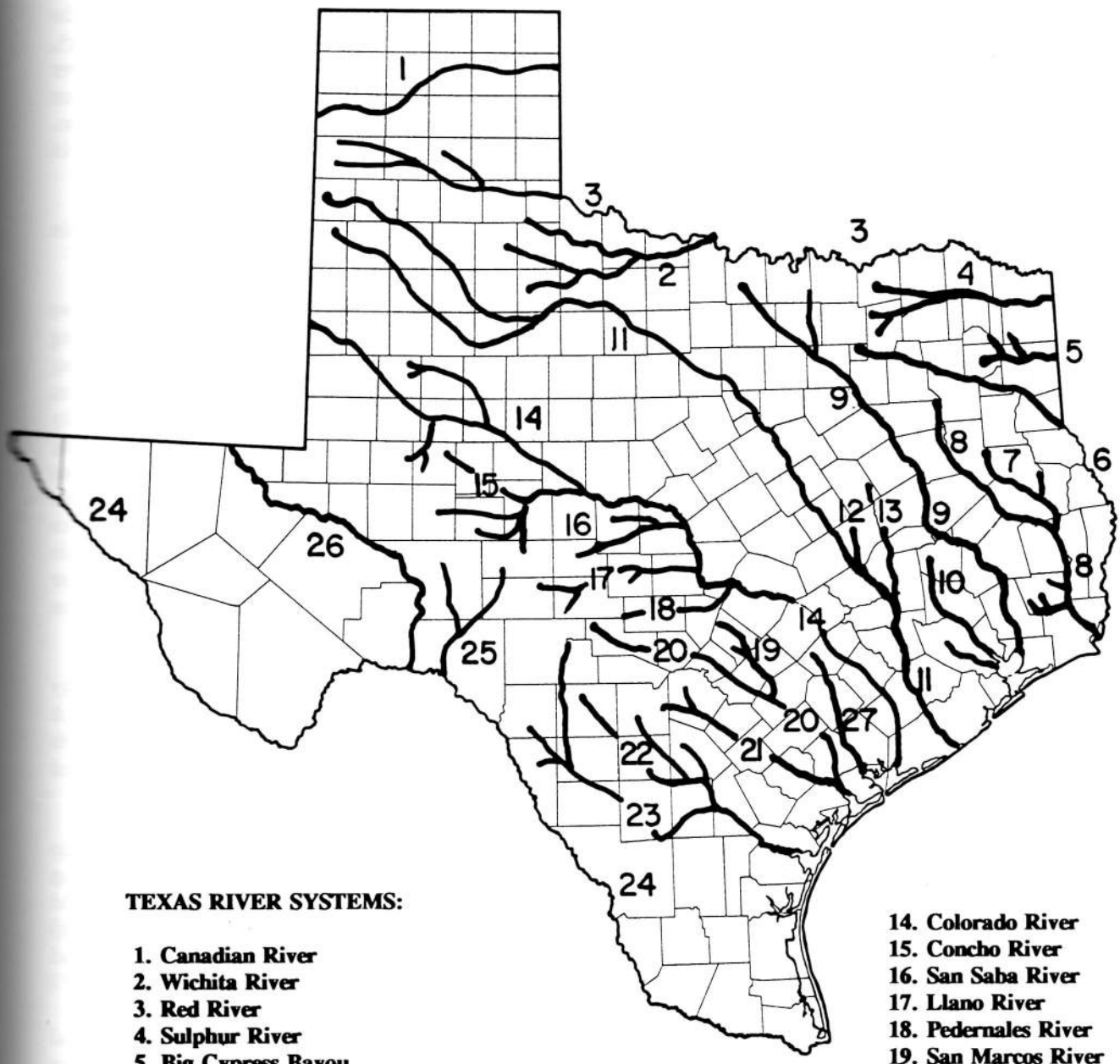


Figure 11. Map of Texas counties.



TEXAS RIVER SYSTEMS:

1. Canadian River
2. Wichita River
3. Red River
4. Sulphur River
5. Big Cypress Bayou
6. Sabine River
7. Angelina River
8. Neches River
9. Trinity River
10. San Jacinto River
11. Brazos River
12. Little Brazos River
13. Navasota River
14. Colorado River
15. Concho River
16. San Saba River
17. Llano River
18. Pedernales River
19. San Marcos River
20. Guadalupe River
21. San Antonio River
22. Frio River
23. Nueces River
24. Rio Grande
25. Devils River
26. Pecos River
27. Lavaca River

Figure 12. Major Texas river systems.

Colorado River (14): travels 965 km from Dawson County in western Texas southeasterly to Matagorda Bay. It has several major tributaries: the Pedernales River (18; 171 km from Kimble County to Lake Travis), the San Saba River (16; about 161 km from near the Schleicher and Menard County lines to the Colorado River), the Llano River (17; about 161 km miles from near Junction to the Colorado River), and the Concho River with three branches (15; 85 km through Tom Green and Concho counties). Recent examination of sites on the first three tributaries suggest that many contain subfossil unionids, but often few or no living specimens. The Concho and Colorado rivers and their associated reservoirs still contain a number of unionid species in relative abundance. Murray (1972) discussed mussels in Lake LBJ.

Lavaca River (27): is a short system running from Hallettsville to Lavaca Bay. It has a limited drainage basin and no apparent reports of major mussel populations or significant harvest.

Guadalupe (20) and San Antonio (21) rivers: the Guadalupe River originates in western Kerr County and flows southeasterly to San Antonio Bay. Middle and upper stretches are often rocky and prone to scouring during flooding resulting in limited mussel faunas. Below the city of Seguin, the Guadalupe River slows and widens; mussels are still relatively common in some of the lower reservoirs, though apparently reduced from previous levels of abundance by overharvest. A tributary, the San Marcos River (19), arises from springs at the city of San Marcos and enters the Guadalupe River 121 km downstream in Gonzales County. Its clear spring waters support few mussels in the upper reaches; lower reaches once held washboards and other species, but recent examination suggests at least some populations are no longer present. Another tributary, the Blanco River, runs about 129 km through Kendall County and meets the San Marcos River just below the city of San Marcos. It is typical of Hill Country streams with apparently limited mussel populations. The San Antonio River originates at springs within the city of San Antonio and flows 290 km south to join the Guadalupe River just before it reaches the coast. Lower stretches are apparently similar to the lower Guadalupe River, but one tributary, the Medina River, is generally rocky and supports few mussels Neck (1989b).

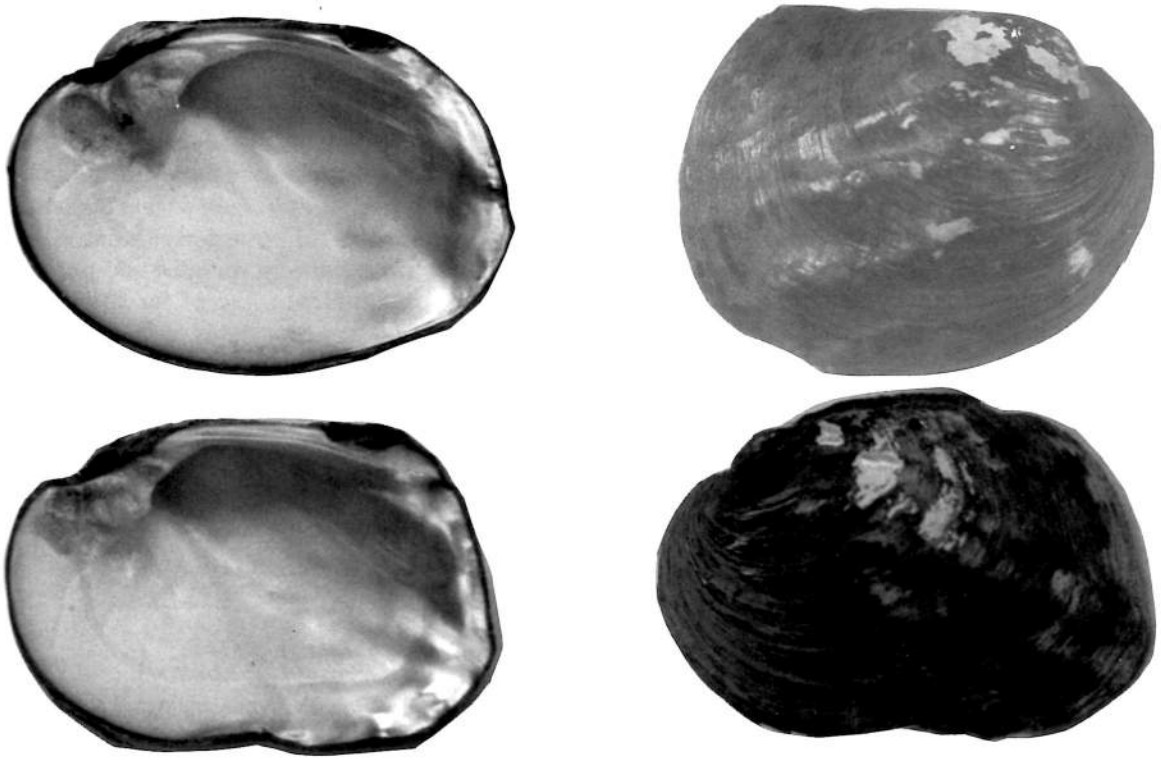
Nueces River (23): originates near Rock Springs and flows southeast to Nueces Bay. Much of its course is rocky and supports few mussels, but some smaller, muddy tributaries reportedly do contain populations. A tributary, the Frio River (22), begins in Real County and runs 402 km to Three Rivers where it joins with the Nueces and Atascosa rivers, and is environmentally similar to the Nueces River. Neck (1987a) discussed unionids in the adjacent Baffin Bay drainage.

Rio Grande (24): has 1,248 of its 3,057 km-length along the southern Texas border with Mexico. A tributary, the Devils River (25), is nearly 161 km in length, but much of its upper reaches are frequently dry except during periods of high runoff. The Pecos River (26), another tributary, arises in southeastern New Mexico and flows south to the Rio Grande just east of Big Bend. Several unique species occur only in this system and adjacent waters in Mexico. Neck and Metcalf (1988) reported on unionids in the lower Rio Grande and Metcalf (1982) described fossil unionids in the system.

Neck (1982b) observed much of the Texas mussel fauna reflected Mississippi Valley origins (a close faunal source), and many eastern Texas rivers had desirably low-gradient waters, but were rather acidic, and hence limiting. Central Texas systems typically have favorable alkaline waters in their central and upper reaches, but often have high gradients and irregular flow rates resulting in scouring during floods and occasional dewatering. The Rio Grande has both high-gradient, hard-bottom areas and low-gradient, soft-bottom habitats, but is influenced by highly alkaline waters from the Pecos River drainage (Neck 1982b). Irregular flows and environmental contamination in the Lower Rio Grande Valley likely negatively impacted mussel diversity and abundance as well.

Central Texas contains several endemic species: Texas pimpleback (Quadrula petrina), golden orb (Q. aurea), false spike (Quincuncina mitchelli), Texas fawnsfoot (Truncilla macrodon), and Texas fatmucket (Lampsilis bracteata); smooth pimpleback (Quadrula houstonensis) may be endemic here as well. Additionally, several species arising from more southern fauna occur in the U.S. only in Texas, including: Tampico pearlymussel, Texas hornshell (Popenaias popei), salina mucket (Potamilus salinasensis), Rio Grande monkeyface (Quadrula couchiana), and Mexican fawnsfoot (Truncilla cognata). Several other genera contain species whose ranges extend only slightly east of the Texas border into Arkansas and Louisiana.

THREERIDGE
Amblema plicata



Threeridge (Amblema plicata): Lake Gonzales, Gonzales County, Texas, August 1992; TPWD. Top left 123 mm shell length; top right 88 mm shell length, bottom 119 mm.

OTHER COMMON NAMES: Roundlake, bluepoint, four-ridge, purple-tip, fluter.

SYNONYMY: (Strecker 1931; Murray and Leonard 1962; Starrett 1971; Oesch 1984).

Unio plicata Say 1817
Amblema costata Rafinesque 1820
Unio undulatus Barnes 1823
Unio perplicatus Conrad 1841
Unio latecostatus Lea 1845
Quadrula undulata Simpson 1900
Crenodonta undulata Ortmann 1912
Amblema plicata costata (Rafinesque), Utterback 1916
Amblema costata (Rafinesque), Parmalee 1967
Amblema plicata (Say), Starrett 1971

Classification of threeridge mussels has been problematic. A complex of forms has been described including: plicata (plicatus), costata, peruviana, undulata, rariplicata, perplicata, quintardi, nippoea, elliotii, pauciplicatus, lincecumii, and brazosensis. The American Fisheries Society (Turgeon et al. 1988) presently recognizes two subspecies: threeridge A. plicata plicata and roundlake A. plicata costata. Indeed, Coker (1919) observed the two forms seemed to intergrade making it difficult or impossible to distinguish them.

DISTRIBUTION: From the San Antonio and Guadalupe river systems into other drainage basins to the north and east; reported from the Nueces River. Strecker (1931) listed a collection on the Rio Grande. Neck (1989a) noted it was not found above Lake Texoma on the Red River.

DESCRIPTION: (Murray and Leonard 1962; Oesch 1984; Fuller 1985).

Size: To at least 148 mm in shell length in Texas [RGH], with other reports to 180 mm in Missouri (Oesch 1984), 140 mm in Kansas (Murray and Leonard 1962), 171 mm in Illinois (Haas 1941), and 178 mm in the northcentral states (Cummings and Mayer 1992).

Shell: Quadrate to suboval or subtrapezoidal (in general, the costata-undulata forms are more elongate and compressed, and the plicata-perplicata forms are more rounded and inflated; both morphological types often occur in the same populations in Texas, and even gradations in shape from one extreme to the other are often typical); shells thick and solid, somewhat inflated, but tapering posterio-ventrally, anterio-dorsal edge gently rounded, ventral margin slightly or strongly rounded, slightly truncated posteriorly; beaks rise above the hinge line, but not highly elevated, beak cavities deep; posterior ridge broadly rounded and obscured by 3-7 heavy, sloping ridges running diagonally; sometimes smooth without ridges, except for fine concentric growth-rest lines; without ornamentation in the anterior-dorsal area.

Shell Teeth: Left valve with two large, triangular, grooved pseudocardinal teeth; right valve with one heavy, triangular, elevated, grooved pseudocardinal tooth. Lateral teeth long, thick, high, lightly striated, and, nearly straight to slightly curved.

External Color: Yellowish- to greenish-brown in young; dark brown to black in older, larger specimens.

Internal Color: White; often purple posteriorly.

Soft Tissues: Generally white in color, with foot and gills sometimes tan or yellowish-brown.

HABITAT: Threeridge occurs on silt and mud to gravel and cobble, or most substrates except deep shifting sand, at water depths 2.5 cm to 1.5 m, at current velocities 0-45.7 cm/second, and in streams, rivers, lakes, and reservoirs (Buchanan 1980; Murray and Leonard 1962; Oesch 1984). Coker (1919) characterized it from slack water areas along river shores or in sloughs; he also commented on its ability to dig-in during droughts and endure dewatering. Threeridges reportedly tolerate low water quality that would be limiting to many other unionids (Starrett 1971). Many Texas populations seem especially abundant in firm mud and mud and fine gravel mixes. Williams and Schuster (1989) found it at depths greater than 9.1 m.

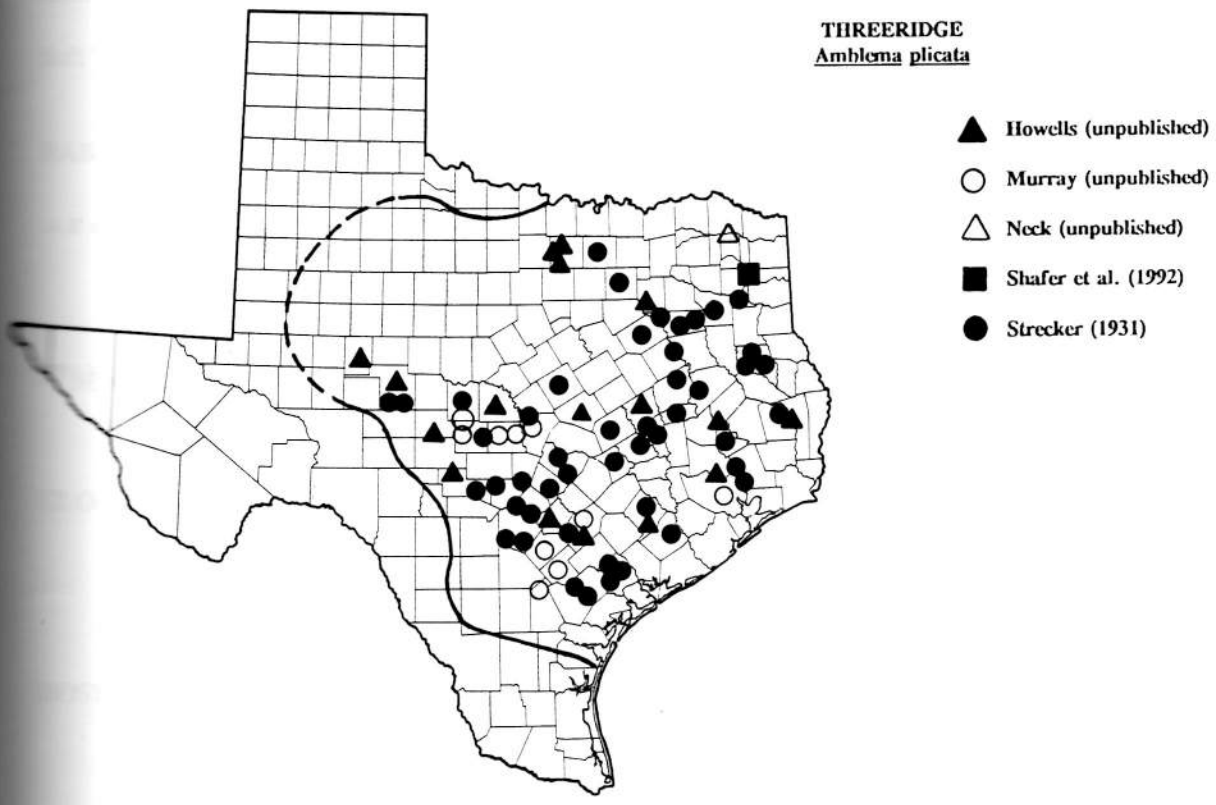
SPAWNING: It is a long-term breeder or bradytictic (Utterback 1915-16). Specimens with mature eggs have been found in July and August in central Texas [RGH]. Stein (1968) reported glochidia present from mid-June through early August in Ohio; she also reported threeridges released white placental masses within 3-4 hours after being placed in laboratory culture dishes. Stein (1969) reported mature females in Ohio at 52 mm shell length and four years old, and mature males at 34 mm shell length and three years old. Littleton (1979) reported gravid females in July and August in central Texas, with the smallest mature female 63 mm in shell length.

GLOCHIDIA: Shell suboval in shape, without hooks or spines, 0.21 x 0.22 mm (Baker 1928). Glochidia metamorphosed in nine days at 70-75° F after infecting a host (Stein 1968).

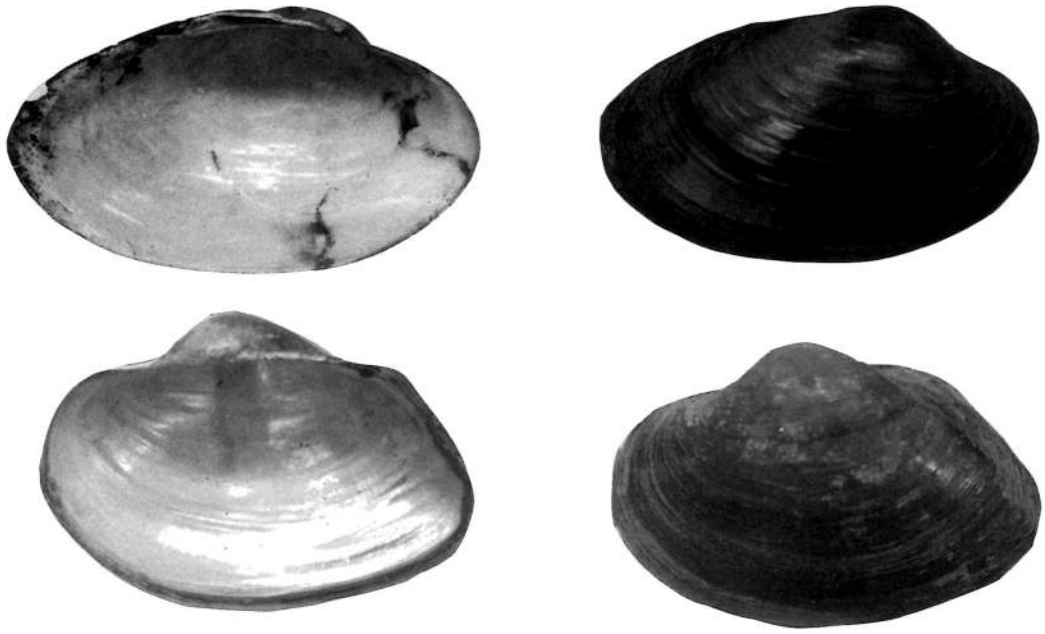
HOSTS: Shortnose gar (Lepisosteus platostomus), northern pike (Esox lucius), highfin carpsucker (Carpiodes velifer), white bass (Morone chrysops), rock bass (Ambloplites rupestris), green sunfish (Lepomis cyanellus), bluegill (L. macrochirus), pumpkinseed (L. gibbosus), warmouth (L. gulosus), white crappie (Pomoxis annularis), black crappie (P. nigromaculatus), largemouth bass (Micropterus salmoides), sauger (Stizostedion canadense), and yellow perch (Perca flavescens) (Coker et al. 1921; Howard and Anson 1922; Baker 1928; Stein 1968; Fuller 1978). Efforts by Stein (1968) to infect several species of minnows (Cyprinidae) and catfishes (Ictaluridae) were unsuccessful; however Fuller (1978) reported channel catfish (Ictalurus punctatus) and flathead catfish (Pylodictis olivaris) as hosts.

ECONOMIC IMPORTANCE: Historically, threeridges were important to the shell-button industry. At present in Texas, threeridges and mapleleafs (Quadrula spp.) are second behind washboard (Megalonaias nervosa) in preference as a source of shell for the cultured pearl industry. Although threeridges can produce natural pearls, they are not usually heavily sought in Texas by pearlers. Elsewhere their shells may attract some limited demand for polished shell chips.

COMMENTS: Classification is confused, and both elongate and rounded forms occur in Texas. Preliminary electrophoretic analysis by TPWD has failed to find genetic differences among morphologically different populations [RGH]; resolution of taxonomic status may await further electrophoretic analysis. Their heavy shells are resistant and often persist in some areas long after living specimens have vanished. Threeridges are one of the most abundant subfossil shells found in many areas of the Llano River, but living specimens are rarely encountered in the upper reaches of many central Texas rivers. Although shells are typically quite solid, some specimens from the Little Brazos River, Robertson County, have been found to be especially thin and brittle posteriorly.



GIANT FLOATER
Anodonta grandis [complex]



Giant floater (Anodonta grandis): Top Concho River, Tom Green County, Texas, January 1993; 141 mm shell length; TPWD. Bottom B.A. Steinhagen Reservoir, Tyler County, Texas, May 1993; 92 mm; TPWD.

OTHER COMMON NAMES: Softshell, stout floater, slop bucket, hogshell, papershell.

SYNONYMY: (Strecker 1931; Murray and Leonard 1962; Murray and Roy 1968; Oesch 1984; Vidrine 1993).

Anodonta grandis Say 1829
Anodonta opaca Lea 1852
Anodonta danielsii Lea 1858
Anodonta corpulenta Cooper 1834
Anodonta stewartiana Lea 1834
Anodonta gigantia Lea 1838
Anodonta grandis corpulenta Cooper 1834
Anodonta grandis bealei Lea 1863
Anodonta grandis lugubris Say 1829
Anodonta texasensis Lea 1829
Anodonta grandis leonensis Lea 1862
Anodonta virens Lea 1852
Anodonta opaca Lea 1852
Anodonta leonensis Lea 1862
Anodonta micans Anthony 1865 var. bealei Lea
Anodonta micans Anthony 1865 var. lugubris Say

Giant floater is sometimes referred to as the Anodonta grandis complex due to the extensive and taxonomically disconcerting variation both between and within populations. The grandis forms are typically called giant floaters, corpulenta forms stout floaters, and stewartiana forms slop buckets. The stewartiana form has been reported from the Nueces, Colorado, and Brazos systems [HDM], was considered grandis by Strecker (1931), and is not recognized by the American Fisheries Society (Turgeon et al. 1988). Some recent publications follow Hoeh (1990) in placing this species in the genus Pyganodon.

DISTRIBUTION: All major drainages.

DESCRIPTION: (Murray and Leonard 1962; Oesch 1984).

Size: To 170 mm shell length in Texas [RGH]; other reports to 180 mm in Missouri (Oesch 1984), 178 mm in Kansas (Murray and Leonard 1962), 185 mm in Oklahoma (Valentine and Stansbery 1971), and 254 mm in the northcentral states (Cummings and Mayer 1992).

Shell: Elliptical to subovate; grandis forms less deep-bodied and more elongate, corpulenta forms are more-deep bodied; thin but solid; dorsal margin and hinge line slightly curved to nearly straight, curved anteriorly, more sharply curved posteriorly, ventrally curved or slightly curved to almost straight; somewhat inflated; beaks swollen and elevated, beak cavities large and deep; posterior ridge broadly rounded; smooth externally except for concentric growth-rest lines.

Hinge Teeth: None; pseudocardinal and lateral teeth lacking.

External Color: Often shiny, tan, light brown, green-brown in younger specimens, occasionally faintly rayed; dark brown to black in larger, older specimens.

Internal Color: Pearly white with bluish overtones; occasionally with a light pink or salmon tint.

Soft Tissues: White to tan, orange-brown to light brown in some mature adults, gills often dark brown; marsupial brood pouches (on outer gills only) form definite pad-like structures.

HABITAT: Giant floater occurs on a wide variety of substrates except rock and shifting sand; probably most commonly over soft mud bottoms; at 0.3-1.5 m deep; and at current velocities 0-57.9 cm/second, often most common in no-flow conditions (Murray and Leonard 1962; Buchanan 1980; Oesch 1984). It may occur on soft, deep mud where heavier-shelled unionids would sink and suffocate (Coker et al. 1921). Giant floater, presumably introduced as glochidia on stocked host fishes have been found in ponds ca. two acres in size which are typically drained every year or two [RGH].

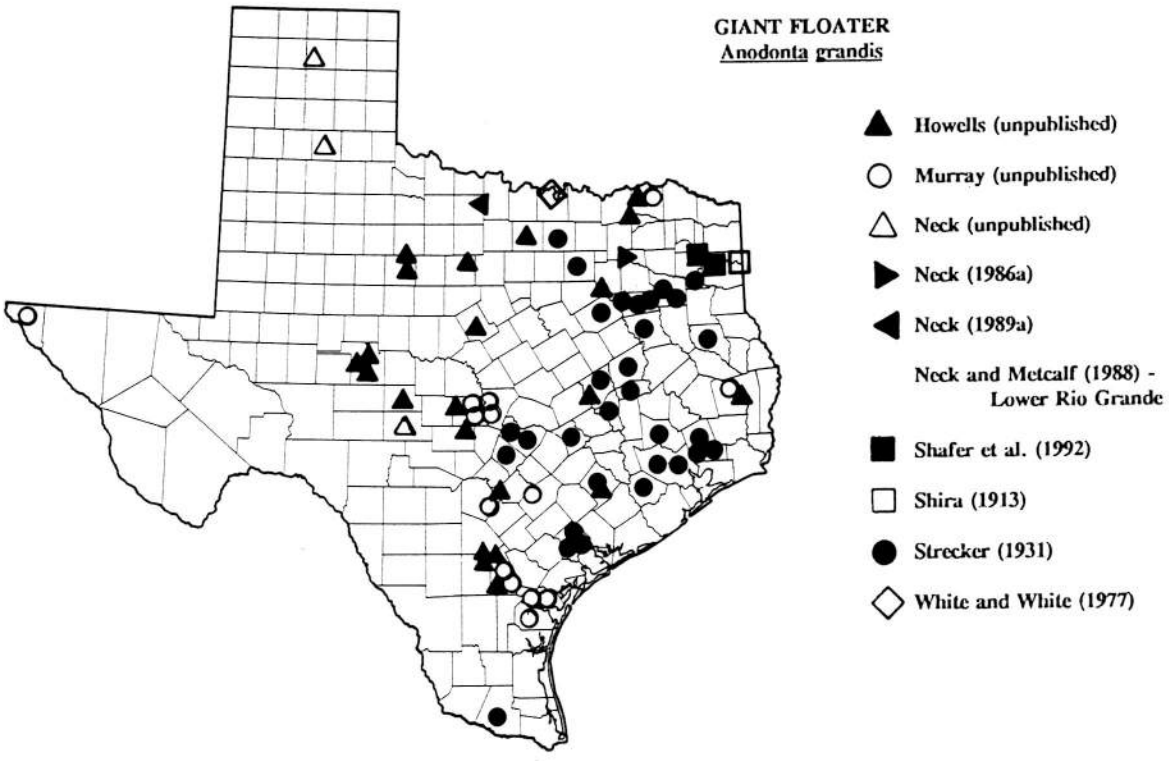
SPAWNING: Breeding occurs from August to April or May, bradytictic (Baker 1928). Littleton (1979) reported gravid females in August in central Texas with a minimum size of 98 mm in shell length; eggs were obtained from south Texas specimens in October and November and glochidia were found in December [RGH].

GLOCHIDIA: Shell large, spade-shaped and spined (one large spine ventrally on each valve), 0.400 x 0.395 mm (largest); russet colored; not in conglutinate masses, but in brownish mucous (Utterback 1915-16); also as subtriangular, asymmetrical, 0.350-0.365 mm in length, 0.350-0.360 mm in height, 0.250-0.258 mm dorsally along the hinge line, each major hook or spine styliform with 20 microstylets in four proximal and one distal row (Hoggarth 1988).

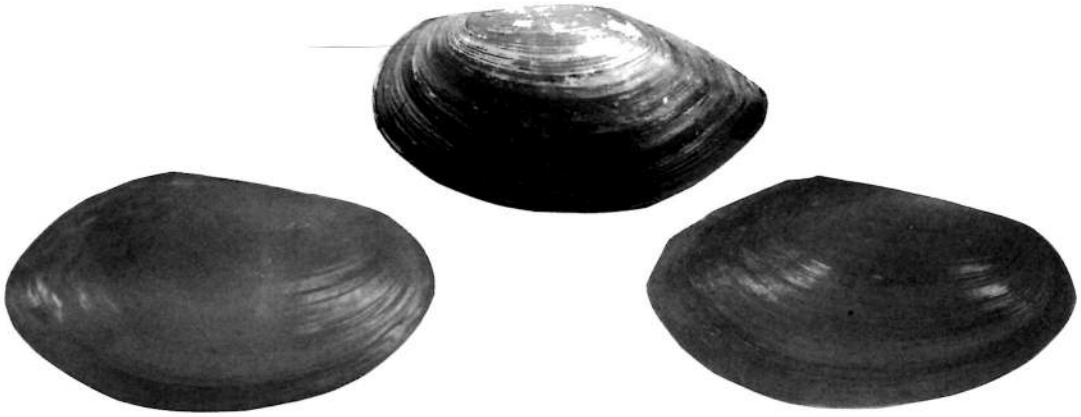
HOSTS: Alligator gar (Lepisosteus spatula), longnose gar (L. osseus), skipjack herring (Alosa chrysochloris), gizzard shad (Dorosoma cepedianum), common carp (Cyprinus carpio), blacknose dace (Rhinichthys atratulus), pearl dace (Margariscus margarita), redfin shiner (Lythrurus umbratilis), blackchin shiner (Notropis heterodon), blacknose shiner (N. heterolepis), central stoneroller (Campostoma anomalum), bluntnose minnow (Pimephales notatus), golden shiner (Notemigonus crysoleucas), common shiner (Luxilus cornutus), creek chub (Semotilus artromaculatus), white sucker (Catostomus commersoni), yellow bullhead (Ameiurus natalis), brown bullhead (A. nebulosus), banded killifish (Fundulus diaphanus), brook silverside (Labidesthes sicculus), brook stickleback (Culaea inconstans) rockbass (Ambloplites rupestris), pumpkinseed (Lepomis gibbosus), green sunfish (L. cyanellus), longear sunfish (L. megalotis), bluegill (L. macrochirus), largemouth bass (Micropterus salmoides), black crappie (Pomoxis nigromaculatus), white crappie (Pomoxis annularis), Iowa darter (Etheostoma exile), johnny darter (E. nigrum), rainbow darter (E. caeruleum), yellow perch (Perca flavescens), and freshwater drum (Aplodinotus grunniens) (Parmalee 1967; Fuller 1978; Trdan and Hoeh 1982; Hoggarth 1992). It is interesting to note that common carp is an introduced species not closely related to native American cyprinids.

ECONOMIC IMPORTANCE: Giant floaters have no commercial importance; however, small numbers may be taken and sometimes sold as trotline bait. Coker (1919) described the species as entirely useless. Reportedly, giant floaters can produce pearls, but they are rare, small, brittle, and sometime hollow, and never of value. It might be noted especially in areas where pearl-producing Tampico pearlymussels (Cyrtonaias tampicoensis) occur, giant floaters are sometimes taken by novices unable to differentiate the species. In early 1992, portions of the Concho River in the city of San Angelo, Tom Green County, were drained and many local residents quickly set upon any mussels beached when water receded. Unfortunately, most specimens killed and opened in search of "Concho River pearls" proved to be giant floaters.

COMMENTS: Some sources suggest giant floaters can generate gasses or trap air bubbles internally and hence float from one location to another (Coker et al. 1921; Harris and Gordon undated). This complex will ultimately require extensive study to resolve taxonomic problems. Aside from differences between the grandis and corpulenta forms, additional variations appear to occur among the strictly grandis types as well.



PAPER PONDSHELL
Anodonta imbecillis



Paper pondshell (Anodonta imbecillis): Top hatchery canal, San Angelo, Tom Green County, Texas, August 1992; 63 mm shell length; TPWD. Bottom Ingram Lake, Kerr County, Texas, June 1992; 73 mm; TPWD.

OTHER COMMON NAMES: Small floater, paper floater, papershell.

SYNONYMY: (Strecker 1931; Murray and Leonard 1962; Murray and Roy 1968; Oesch 1984).
Anodonta imbecillis Say 1829
Anodonta imbecillis horda Gould 1885

Although sometimes listed as Lastena ohioensis Rafinesque 1820 and Anodonta ohiensis Rafinesque, Gordon (1989) indicated this reference was to pink papershell (Potamilus ohiensis) and not to this species; Turgeon et al. (1988) also assign this species to Say 1829. Further, although typically spelled imbecillis, Murray and Leonard (1962) indicated using a single "l" was actually correct. Some recent publications follow Hoeh (1990) in placing this species in the genus Utterbackia.

DISTRIBUTION: All major drainages.

DESCRIPTION: (Murray and Leonard 1962; Oesch 1984; Fuller 1985).

Size: To 90 mm in shell length in Texas [RGH], with reports to about 100 mm in Missouri (Oesch 1984), 88.9 mm in Kansas (Murray and Leonard 1962), and 102 mm in the northcentral states (Cummings and Mayer 1992).

Shell: Oblong to elongate-oblong, subrectangular; inflated or compressed; very thin and fragile, often translucent in smaller specimens; beaks low and not projected above hinge line, beak cavities very shallow; hinge line relatively straight, rounded anteriorly, gently rounded ventrally, centrally pointed posteriorly; posterior ridge rounded to broadly rounded; externally typically unsculptured except for concentric growth rings, weak ridges reported present in some specimens.

Shell Teeth: Both pseudocardinal and lateral teeth lacking.

External Color: Off-white to tan or black, often with lime-green to dark green highlights; some individuals have green, yellow-green, or black rays posteriorly; often glossy.

Internal Color: Shiny bluish-white, sometimes with pink tints; dead specimens may be more chalky-white with little suggestion of glossiness; external coloration may be visible internally in thin-shelled individuals.

Soft Tissues: Tan to off-white in color; marsupia brownish; outer gills containing glochidia may be orange to tan or white [RGH].

HABITAT: Paper pondshell occurs on a variety of bottom types but is most common on silt, silt and sand, or sometimes gravel and cobble (Buchanan 1980; Murray and Leonard 1962). It may survive on deep, soft silt where other heavier-shelled mussels cannot endure (Coker et al. 1921); specimens taken above the dam at Ingram Lake, Kerr County, Texas, occur on silt so soft even small Asian clams (Corbicula spp.) sink into the substrate [RGH]. It occupies rivers, streams, reservoirs, and lakes, most often in still or slowly-moving waters (Murray and Leonard 1962). This species may become more abundant in impounded waters (Gordon and Layzer 1989).

SPAWNING: Unlike most American unionids, paper pondshell is predominately hermaphroditic (van der Schalie 1966). It is often considered a bradytictic or long-term breeder where eggs, embryos, or glochidia may be carried through the winter before release in the spring (Heard 1975); however, they may also be able to produce multiple broods per year or a rapid succession of broods during the warmer months (Gordon and Layzer 1989; Heard 1975). Adults containing glochidia were taken in April, May, and July-November in Texas [RGH]. Littleton (1979) also found a gravid female 46 mm in shell length in October in the Navasota River, Texas.

GLOCHIDIA: Golden brown in color; broad and spade-shaped with a straight hinge line, spined, 0.31 x 0.29 mm (Surber 1912, 1915; Utterback 1915-16); also, reported as subtriangular, 0.291-0.313 mm shell length, 0.289-0.306 mm shell height, 0.240-0.256 mm dorsally along the hinge line, hook or spine in each valve styliform and appearing as a broad, triangular plate with microstylets in rows near the distal margin (Hoggarth 1988).

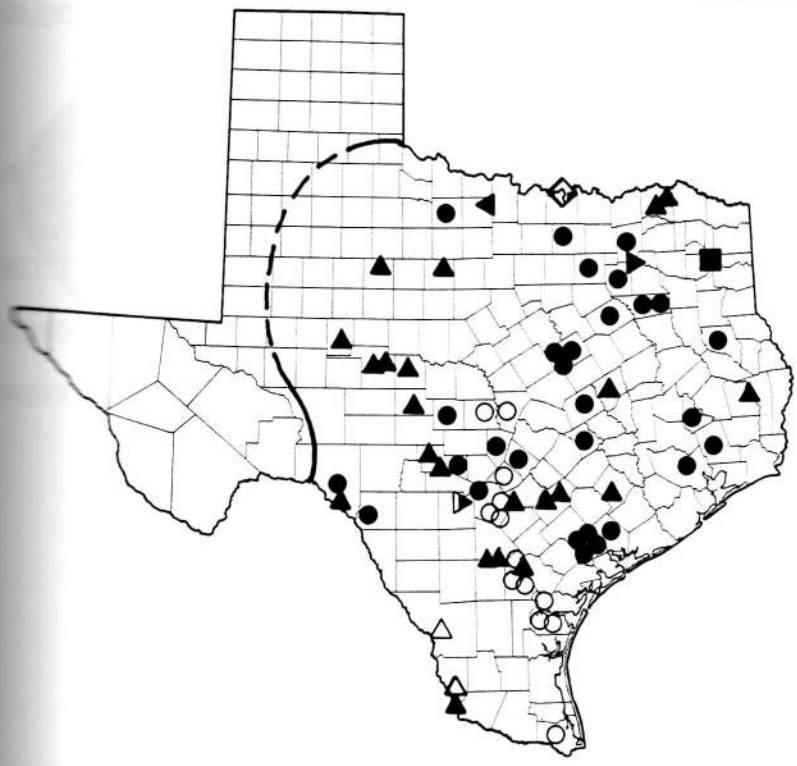
HOSTS: Howard (1915) indicated juveniles developed within the gills of the parent without a fish host; similarly, Baker (1928) reported paper pondshells release light, floating larvae which do not require a fish host. However, Tucker (1927) reported glochidia on green sunfish (Lepomis cyanellus), and Fuller (1978) listed creek chub (Semotilus atromaculatus) as a host; other host species reported more recently include banded killifish (Fundulus diaphanus), mosquitofish (Gambusia affinis), rock bass (Ambloplites rupestris), largemouth bass (Micropterus salmoides), warmouth (Lepomis gulosus), bluegill (L. macrochirus), pumpkinseed (L. gibbosus), dollar sunfish (L. marginatus), and yellow perch (Perca flavescens) (Stern and Felder 1978; Trdan and Hoeh 1982; Hoggarth 1988), and greenthroat darter (Etheostoma lepidum) [RGH].

ECONOMIC IMPORTANCE: None.

COMMENTS: Shell edges may seal imperfectly so, when living specimens are removed from the water, air may enter the shell cavity and cause them to float when released [RGH]; this suggests some intolerance to drought and dewatering. Some literature suggests certain anodontids may be able to generate gasses or trap air bubbles which in turn allow them to float from one location to another (Coker et al. 1921; Harris and Gordon undated). Paper pondshell is apparently a short-lived, but fast-growing species (Coker et al. 1921).

NOTE: Since this manuscript was drafted, questions have been raised about the taxonomic status of some specimens from Texas and Louisiana which are atypically deep bodied and rounded posteriorly. It is possible a second species may also be present.

PAPER PONDSHELL
Anodonta imbecillis



▲ Howells (unpublished)
○ Murray (unpublished)
△ Neck (unpublished)
▶ Neck (1986a)
◀ Neck (1989a)
▷ Neck (1989b)
■ Shafer et al. (1992)
● Strecker (1931)
◇ White and White (1977)

FLAT FLOATER
Anodonta suborbiculata

Flat floater (Anodonta suborbiculata): Henderson Swamp, St. Martin Parish, Louisiana, July 1986; 100 mm shell length; HMNS.

OTHER COMMON NAMES: Heelsplitter, pearl leader.

SYNONYMY: (Murray and Leonard 1962; Oesch 1984).
Anodonta suborbiculata Say 1831
Anodon suborbiculatus Sowerby 1867

DISTRIBUTION: Eastern Texas; from the Brazos River north and east; range apparently expanding in Texas, not known in Texas during Strecker's review (Strecker 1931).

DESCRIPTION: (Murray and Leonard 1962; Oesch 1984; Fuller 1985).

Size: To at least 136 mm shell length in Texas [RGH], with a report to 350 mm or more in Missouri (Oesch 1984).

Shell: Large, nearly circular; inflated or compressed; thin, fragile, often cracks when dry; dorsal margin straight or slightly curved, curved anteriorly and ventrally, somewhat angular posteriorly; beaks low, flat, compressed, and narrow, beak cavities shallow or absent; externally smooth except for slight roughness at the umbonal ridge and sometimes two divergent rows of tubercles on beaks.

Shell Teeth: None; no pseudocardinal or lateral teeth.

External Color: Shiny; yellow-tan, yellow, olive or dark brown; fine green rays sometimes present.

Internal Color: Bluish-white to white, occasionally with pink or salmon tints, very pearly.

Soft Tissues: Foot deep orange, some muscles also orange, gills olive, other soft tissues pale tan to nearly transparent.

HABITAT: Flat floater is found in flood-plain streams, lakes, and swamps, often in deep mud and silt; it may benefit from construction of impoundments (Oesch 1984). It often occurs in quiet waters along muddy or sandy banks (Scammon 1906).

SPAWNING: This species was listed by Utterback (1915-1916) as a long-term bradytictic breeder. Hoggarth (1988) reported glochidia taken from a specimen collected in mid-October.

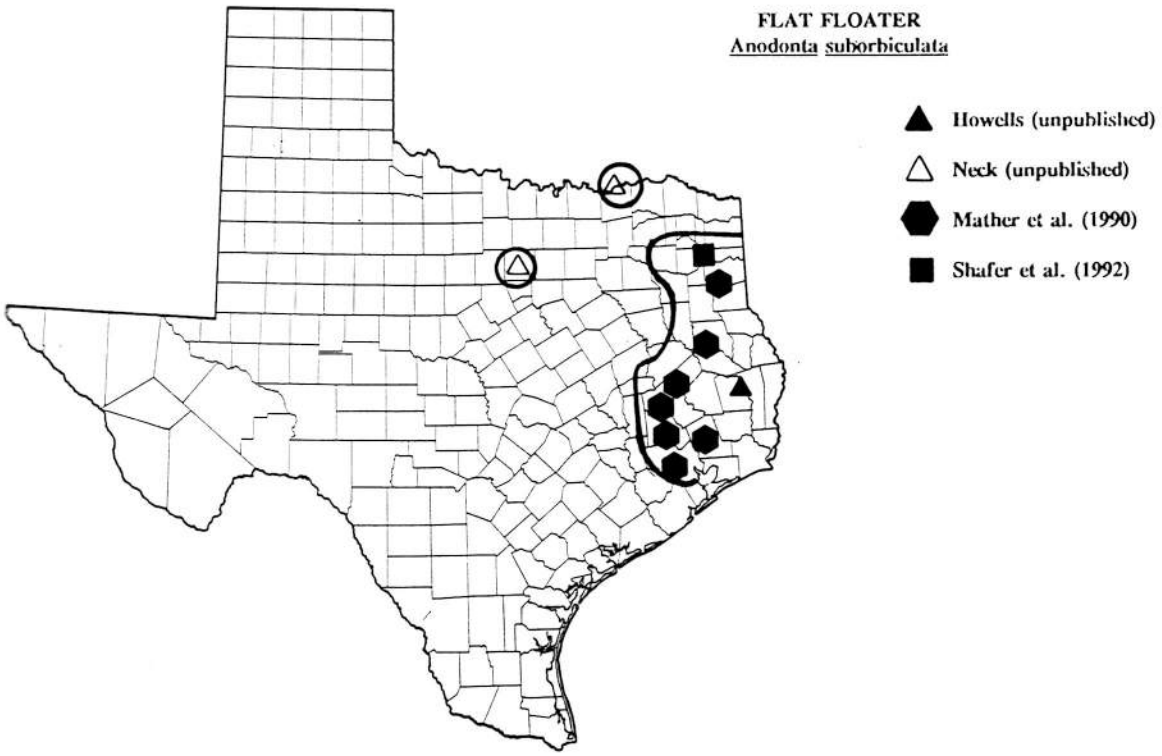
GLOCHIDIA: Shell large, spade-shaped and spined (one large spine ventrally on each valve), 0.325 x 0.320 mm; russet colored with bluish spots; not in conglutinate masses, but in brownish mucus (Utterback 1915-16); also as subtriangular, 0.323-0.328 mm shell length, 0.320-0.328 mm shell height, 0.231-0.237 mm dorsally along the hinge line; hook styliform with about 40 lance-shaped microstylets (Hoggarth 1988).

HOSTS: Several centrarchids and percids have recently been identified as hosts (M.C. Barnhart, Southwest Missouri State University, Springfield; pers. comm.).

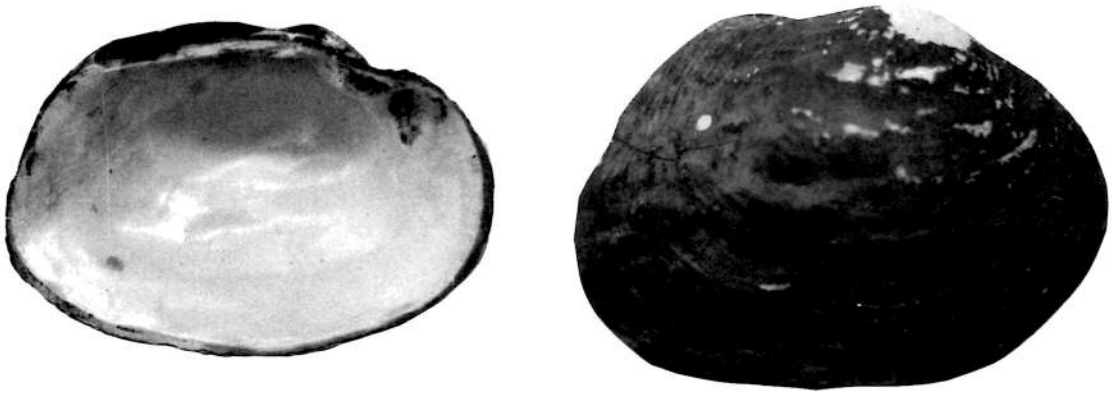
ECONOMIC IMPORTANCE: None.

COMMENTS: Flat floater is poorly known in Texas waters.

NOTE: Specimens collected by TPWD in B.A. Steinhagen Reservoir (1993) on the Neches River and again in Sam Rayburn Reservoir (1995) on the Angelina River resemble flat floater but are less deep bodied, more inflated, dark brown to black in color when large, and often have beaks which slightly elevate above the hinge line. Females taken in B.A. Steinhagen Reservoir in December carried glochidia which resembled those of flat floater. These glochidia encysted and transformed on green sunfish (Lepomis cyanellus), longear sunfish (L. megalotis) and channel catfish (Ictalurus punctatus) [RGH]. Similar specimens have also been found by P. Hartfield (U.S. Fish and Wildlife Service, Jackson, Mississippi) in Mississippi and may represent an undescribed species.



ROCK-POCKETBOOK
Arcidens confragosus



Rock-pocketbook (Arcidens confragosus): B.A. Steinhagen Reservoir, Tyler County, Texas, May 1993; 98 mm shell length; TPWD.

OTHER COMMON NAMES: Rock shell, bastard shell, grandmaw, queen, black pocketbook.

SYNONYMY: (Murray and Leonard 1962; Oesch 1984).
Alasmodonta confragosa Say 1829
Arcidens confragosus, Simpson 1900

DISTRIBUTION: From the Guadalupe River system north and east. Mather (1985) reported it from an oxbow lake in Gonzales County, Texas, adjacent to the San Marcos River.

DESCRIPTION: (Murray and Leonard 1962; Oesch 1984).

Size: To 160 mm shell length in Texas [RGH], with reports to 111 mm (Oesch 1984) and 127 mm (Buchanan 1980) in Missouri, 60 mm in Kansas (Murray and Leonard 1962), and 178 mm in the northcentral states (Cummings and Mayer 1992).

Shell: Quadrate to subrhomboidal, slightly elongate in some; inflated; solid to subsolid; stout, but not especially thick-shelled, moderately heavy in some; dorsal margin nearly straight, rounded anteriorly and ventrally, diagonally truncated posteriorly and nearly straight; beaks full and elevated above hinge line, beak cavities moderately deep; posterior ridge broadly rounded; one of the most heavily sculptured unionids, prominent beak sculpturing extends down over the valves in an irregular series of ridges and cross ridges; growth and rest periods also produce concentric shell ridges.

Shell Teeth: Left valve with two pseudocardinal teeth, high, elongate, thin and compressed, curved, serrate or emarginate, anterior-most tooth low, thin, and rough; right valve with a single pseudocardinal tooth high, thin, flat-topped, striated, and parallel to the hinge line. Lateral teeth reduced to a single sharp-edged ridge in both valves, or absent.

External Color: Shiny; bright green to yellow green in young, often with alternating green, yellow, and brown rays; becomes tan to darker green with age; some older specimens nearly black.

Internal Color: White, iridescent posteriorly.

Soft Tissues: White to tan; gills light brown, darker in gravid individuals, spotted or striated when embryos are present; marsupia pad-like.

HABITAT: Rock-pocketbook may occur on mud, sand, or gravel; often in still or slow-moving waters, but may tolerate moderate currents; in flow rates from less than 6 cm/second to relatively swift conditions; at depths of 10-107 cm to much deeper waters; and may prefer medium- to large-sized rivers (Baker 1928; Murray and Leonard 1962; Buchanan 1980; Oesch 1984). Goodrich and van der Schalie (1944) indicated it prefers mud bottoms and deep water. It tolerates some reservoirs in Texas as indicated by specimens in the Trinity University collection taken from Lake Buchanan, Burnet County, Texas [HDM], specimens from Lake Lewisville (Neck 1990a), and others taken by TPWD in B.A. Steinhagen Reservoir, Tyler County, Texas [RGH].

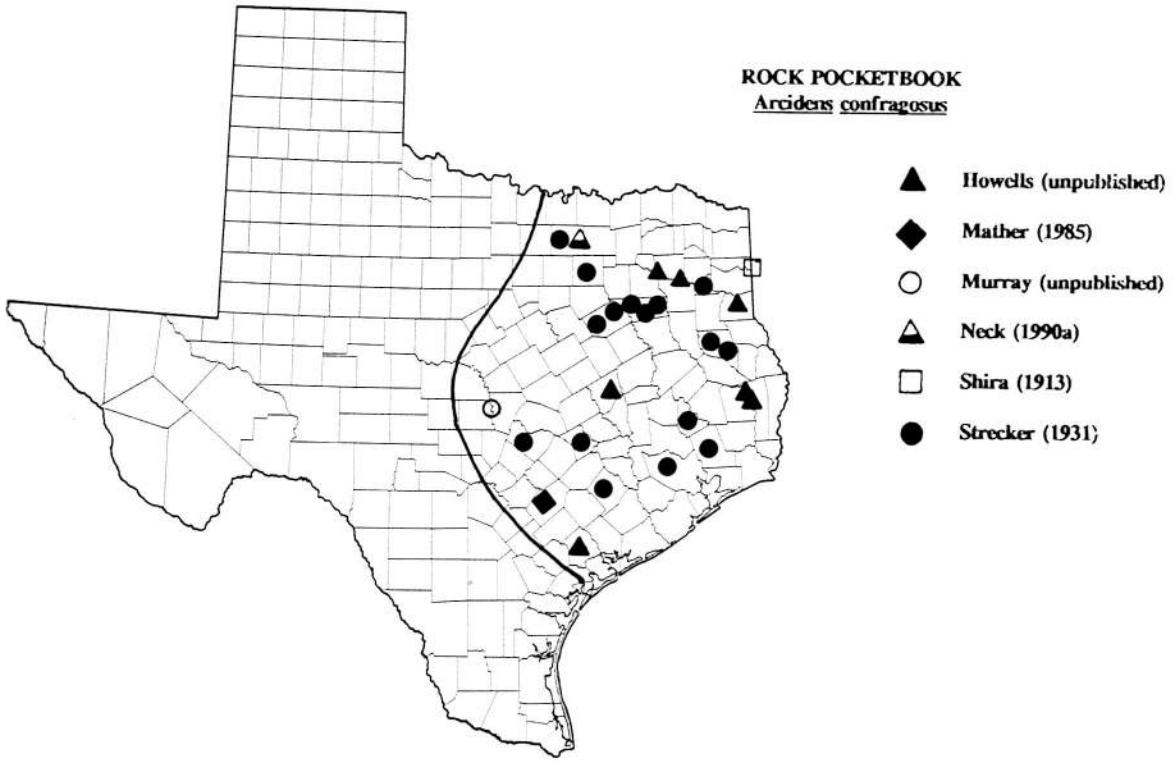
SPAWNING: The species is considered a long-term breeder or bradytictic; it probably spawns September through June (Baker 1928); Hoggarth (1988) reported glochidia taken in early November.

GLOCHIDIA: Shell subtriangular with an undulate hinge line; 0.355 x 1.350 mm [sic?] (Utterback 1915-1916); also as pear-shaped (pyriform), 0.325-0.363 mm shell length, 0.289-0.299 mm shell height, 0.231-252 mm dorsally along the hinge line, with dense rosette sculpturing over the valves; hook or spine a very strongly biconcave, triangular plate with about 80 pyramid-shaped microstylets (Hoggarth 1988).

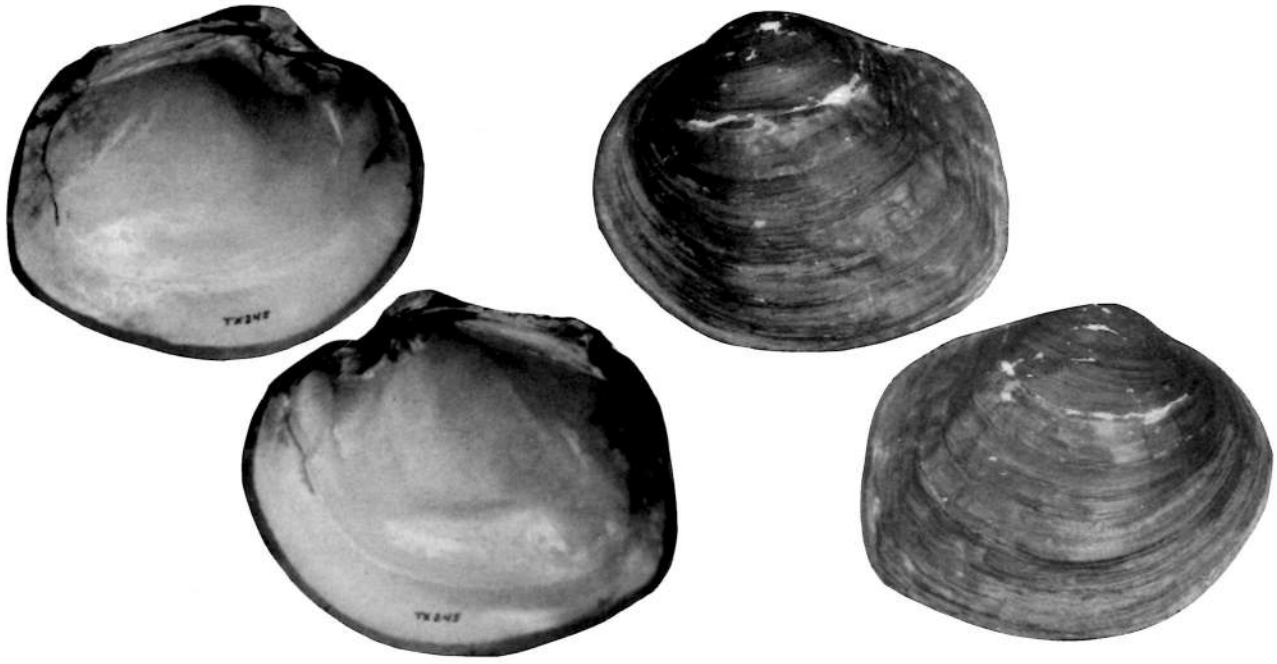
HOSTS: American eel (Anguilla rostrata), gizzard shad (Dorosoma cepedianum), white crappie (Pomoxis annularis), rock bass (Ambloplites rupestris), and freshwater drum (Aplodinotus grunniens) (Fuller 1978; Surber 1913); also channel catfish (Ictalurus punctatus) [RGH].

ECONOMIC IMPORTANCE: None.

COMMENTS: Rock-pocketbook is often rare to uncommon throughout its range. Coker (1919) listed it as rare but widely distributed. Beaks are often closer to center along the dorsal hinge line than in threeridge (Amblema plicata) and washboard (Megalonaias nervosa) where beaks are positioned more anteriorly; never as thick-shelled.



OUACHITA ROCK-POCKETBOOK
Arkansia wheeleri
FEDERAL ENDANGERED SPECIES



Ouachita rock-pocketbook (Arkansia wheeleri): Pine Creek, Lamar County, Texas, November 1992; 84 mm shell length; J.A.M. Bergmann, O.M.C., Boerne, Texas, collection.

OTHER COMMON NAMES: Arkansas rock-pocketbook, Wheeler's rock-pocketbook.

SYNONYMY: (Burch 1973; Martinez and Jahrsdoerfer 1991; Harris and Gordon undated).
Arkansia wheeleri Ortmann and Walker 1912
Arcidens wheeleri (Ortmann and Walker 1912), Clark 1981

DISTRIBUTION: Recently found in Pine and Sanders creeks, Lamar County, Texas (J.A.M. Bergmann and C.M. Mather; pers. comm.); previously known only from the Little River drainage, Sevier and Little River counties, Arkansas, and the Kiamichi River in Oklahoma (Martinez and Jahrsdoerfer 1991; Harris and Gordon undated).

DESCRIPTION: (Burch 1973; Martinez and Jahrsdoerfer 1991; Anonymous 1993; Harris and Gordon undated).

Size: Texas specimens 84 mm x 79 mm and 57 x 48 mm [RGH]; maximum shell size 76-102 mm in Arkansas (Harris and Gordon undated), and 102 mm shell length (Anonymous 1993) and 120 x 73 mm (Martinez and Jahrsdoerfer 1991) in Oklahoma.

Shell: Round to triangular; moderately inflated; moderately thick to thick, less so posteriorly; curved anteriorly and ventrally to the posterior ridge, straight or slightly curved to truncated posteriorly above the posterior ridge, slightly curved dorsally; beaks raised above hinge line, beak cavities moderately deep; tubercles of beak sculpturing restricted to the first 3-4 mm of the beak; posterior ridge broadly rounded; central and posterior shell covered with slight undulations or flutings on the posterior half of the shell; growth lines evident; somewhat silky luster externally.

Shell Teeth: Two left and one right pseudocardinal teeth large, well developed, triangular, not compressed; ventral lateral tooth shortened and elevated into a high flange, dorsal lateral tooth reduced or absent.

External Color: Typically brown to black, without rays; Texas specimens substantially lighter in color than typical for the species elsewhere.

Internal Color: White.

Soft Tissues: Unreported.

HABITAT: Harris and Gordon (undated) characterized it as occurring in medium-sized rivers, in backwater or slackwater areas adjacent to the main channel, and from muddy or silty substrates. Also reported in pools in small, slow-flowing rivers, and as preferring cobble-gravel bottoms; also in sand (Anonymous 1992). Vaughn (1991) and Vaughn et al. (1993) indicated this species always occurred within large mussel beds containing a diversity of species.

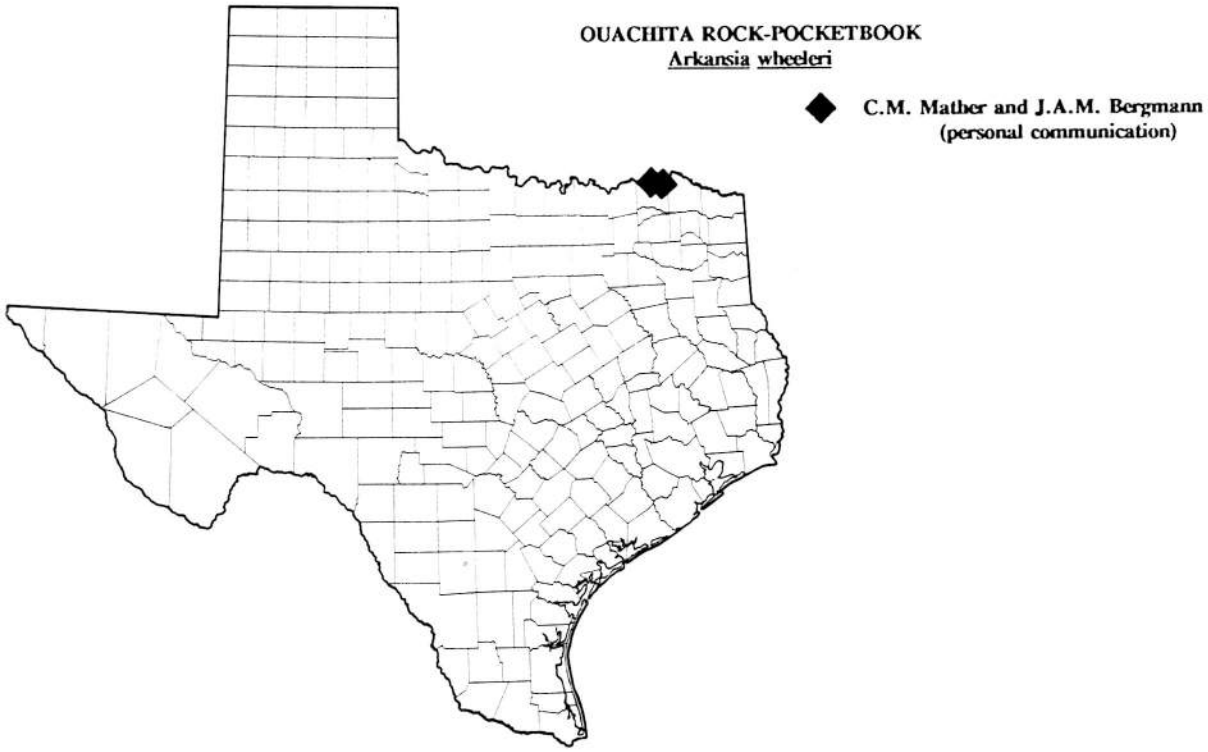
SPAWNING: Unreported.

GLOCHIDIA: Unreported.

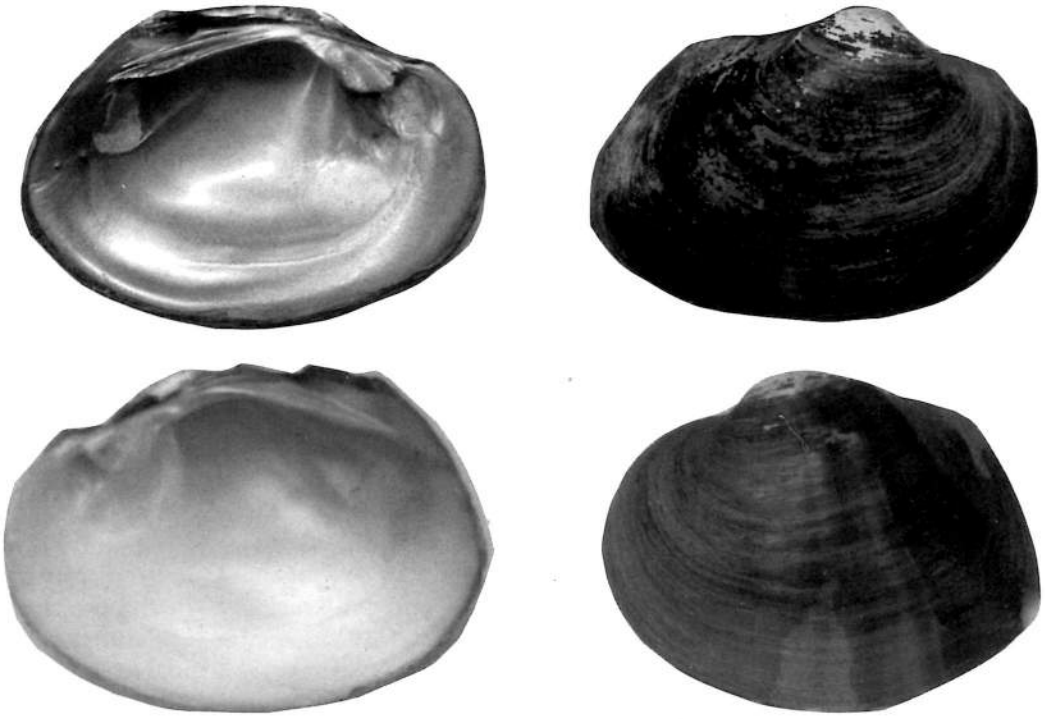
HOSTS: Unreported; however, Vaughn et al. (1993) indicated two cyprinids, redfin shiner (Lythrurus umbratilis) and a second shiner (Notropis sp., c.f. rubellus), were the most likely fish hosts.

ECONOMIC IMPORTANCE: None.

COMMENTS: Ouachita rock-pocketbook is similar to rock-pocketbook (Arcidens confragosus). In rock-pocketbook, beak sculpturing extends well beyond the first 3-4 mm of beak and pseudocardinal teeth are reported as compressed and laminate (Burch 1973). However, some large (> 100 mm shell length) rock-pocketbook specimens from Texas have enlarged, non-laminate pseudocardinal teeth which show little signs of being compressed (especially the right and posterior left pseudocardinal teeth); rock-pocketbook specimens of this size are often slightly more elongate and straight-margined ventrally than the more rounded shape of Ouachita rock-pocketbook [RGH]. The confluences of Pine and Sanders creeks, Texas, with the Red River are in close proximity to where the Kiamichi River, Oklahoma, joins the Red River. Several other tributary streams enter the Red River from Texas near the Kiamichi River as well and should be examined with this species in mind.



TAMPICO PEARLYMUSSEL
Cyrtonaias tampicoensis



Tampico pearlymussel (Cyrtonaias tampicoensis): Nasworthy Reservoir, Tom Green County, Texas, April 1992; top 94 mm shell length; bottom 62 mm; TPWD.

OTHER COMMON NAMES: Purple shell mussel, purple mussel, Concho River pearl mussel.

SYNONYMY: (Strecker 1931; Burch 1973; Fuller 1975; Metcalf 1982).

Unio tampicoensis Lea 1838
Unio berlandierii Lea 1857
Unio heermanii Lea 1861
Lampsilis tampicoensis Lea, Simpson 1900
Cyrtonaias tampicoensis (Lea 1838), Fischer and Crosse 1894 (see Fuller 1975)
Cyrtonaias grandensis, Metcalf 1982

Strecker (1931) listed three subspecies (under Lampsilis): C. t. tampicoensis, C. t. berlandierii, and C. t. heermanii. Additionally, the U.S. Fish and Wildlife Service lists a Mexican subspecies C. t. tecomatensis as endangered (U.S.F.W.S., Endangered and Threatened Wildlife and Plants, January 1, 1986. 50 CFR 17.11 AND 17.12). Fuller (1975) discussed systematic position of the genus.

DISTRIBUTION: Within Texas, Tampico pearlymussel is native to the Rio Grande, Nueces, Frio, San Antonio, Guadalupe, and Brazos river systems. Local populations in parts of the Trinity River are probably introductions. Additionally, Mather (1989) reported a specimen from Lake Texoma on the Red River (also a probable introduction). Other populations occur in Mexico as far south as the Panuco River of Tamaulipas and Verracruz (Neck 1990b).

DESCRIPTION: (Burch 1973; RGH).

Size: To at least 143 mm shell length in Texas; typical adults average 100-120 mm in length; maximum size probably reaches or exceeds about 180 mm [RGH].

Shell: Generally oval, occasionally subrectangular; some misshaped shells may be shortened posteriorly (resemble in outline marine quahog or hard clam, Mercenaria); moderately thick, solid; occasionally slightly winged; somewhat inflated; dorsal margin slightly curved to nearly straight, anteriorly rounded, ventrally rounded to almost straight, posteriorly slightly rounded, weakly pointed posterio-ventrally; beaks raised above hinge line, beak cavities relatively deep; posterior ridge broadly rounded; shell surface generally smooth except for concentric growth rings.

Shell Teeth: Left valve with two pseudocardinal teeth pointed to round pointed, striated, anterior tooth sometimes strongly squared to round pointed, and larger than posterior tooth; right valve has two pseudocardinal teeth (or one pseudocardinal tooth and a large anterior denticle), anterior tooth is often squared and strongly striated, posterior tooth broadly rounded and striated; lateral teeth moderately long, very slightly curved and lightly striated, elevated, leaf-like, compressed (posteriorly-shortened individuals may show more curvature in lateral teeth); among the two teeth in the left valve, the ventral lateral tooth often slightly shorter than the dorsal tooth.

External Color: Dull or shiny; reddish-brown to dark brown or black, grayish in some individuals; juveniles may show very faint, thin (rarely broad) darker rays, some populations may retain rays into early adulthood (atypical of most).

Internal Color: Most frequently purple, but may be white, pink, salmon, or orange, rarely a combination of two or more colors; small juveniles often exhibit white nacre with darker coloration developing gradually.

Soft Tissues: Pale cream to tan, gills slightly milky when glochidia are present; glochidia in marsupia completely occupy the outer gills.

HABITAT: Tampico pearlymussel often occurs on mud, mud and sand, mud and gravel, or less frequently on cobble or rock, but is not typically present in deep silt or shifting sands; it may be present in slow-flowing, mud-bottomed rivers or gravel-bottomed streams with swifter currents; the species adapts well to some reservoirs. Individuals attempting pearl culture with this species have successfully maintained the species in small ponds where culture specimens have reportedly reproduced [RGH].

SPAWNING: The species is probably a long-term, bradytictic breeder; females with glochidia have been found in central Texas in May and June (Nasworthy Reservoir, Tom Green County), others with developed eggs have been found in July and August (Lake Gonzales, Gonzales County), and a female with early eggs was found in Nasworthy Reservoir in September [RGH]; a single female carrying eggs in various stages of development was found in mid-November and four females with apparently-fertile eggs were present among a group of specimens held at TPWD's Heart of the Hills Research Station (Kerr County) in January and March. A female 73 mm shell length and 48 mm in shell height carried mature glochidia [RGH]. Fuller (1975) found ovigerous females in May and August, and postulated glochidia may be retained over the winter.

GLOCHIDIA: Shell moderate sized, 0.200 x 0.150 mm, without hooks or spines, generally D-shaped with a relatively long, straight hinge line [RGH].

HOSTS: In laboratory tests, glochidia appeared to encyst on several centrarchids, but successful transformation to the juvenile stage was not confirmed [RGH]; otherwise, unreported.

ECONOMIC IMPORTANCE: Although Tampico pearlymussels were largely spared the extensive harvest for button shell seen in the Mississippi River drainage around the turn of the century, some limited harvest for button production did occur. In the Rio Grande Valley the Continental Button Factory took shells from 1928 (Garrett 1929) until after World War II, and local military personnel at Fort Brown apparently used shell for buttons as well (Neck 1990b); additionally, local residents along the Llano River have reported shell

HABITAT: Spike may be found on many substrates except shifting sand, but often in rivers with sand-gravel or mud-gravel bottoms (Oesch 1984). Murray and Leonard (1962) listed it from soft deep mud, mud-sand, rock-sand, and mud. It occurs from very shallow waters to 5.7 m depth, and from standing waters to flow rates of 51.8 cm/second (Buchanan 1980). Stansbery (1965) considered spike as highly intolerant of pollution.

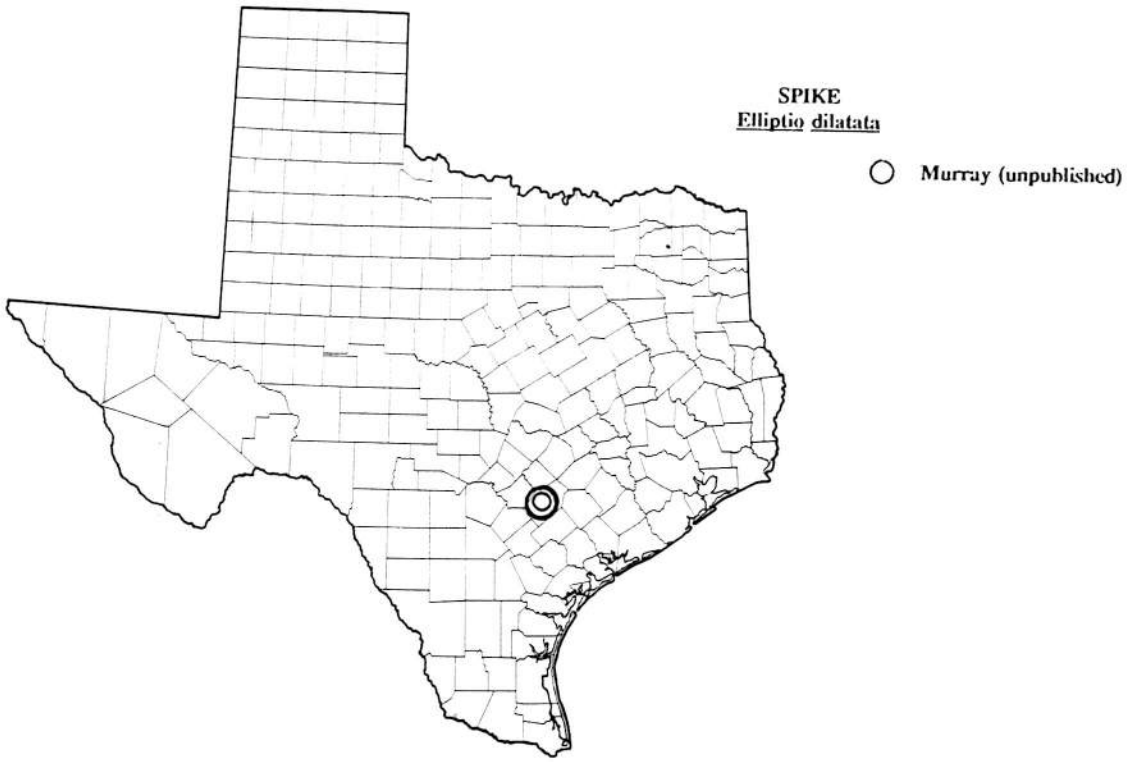
SPAWNING: It is a short-term or tachytictic breeder spawning mid-May to August (Ortmann 1919). Hoggarth (1988) found glochidia in mid-May, and Jirka and Neves (1992) reported them from late April through early July. Jirka and Neves (1992) reported the smallest mature female at Age 4 and 49.7 mm in shell length, and all males mature at Age 4; they also recorded a single case of hermaphrodism.

GLOCHIDIA: Medium-sized, 0.200 x 0.220 mm, spineless, hinge line straight or slightly depressed (Utterback 1915-16). Jirka and Neves (1992) described glochidia as 0.249 (S.D. 0.007) x 0.235 (S.D. 0.004) mm, hinge line 0.160 (S.D. 0.004) mm, and with a smoothly rounded outline. Hoggarth (1988) reported the shell as subelliptical, 0.210-0.219 mm long, 0.219-0.225 mm high, and 0.140-0.147 mm dorsally along the hinge line.

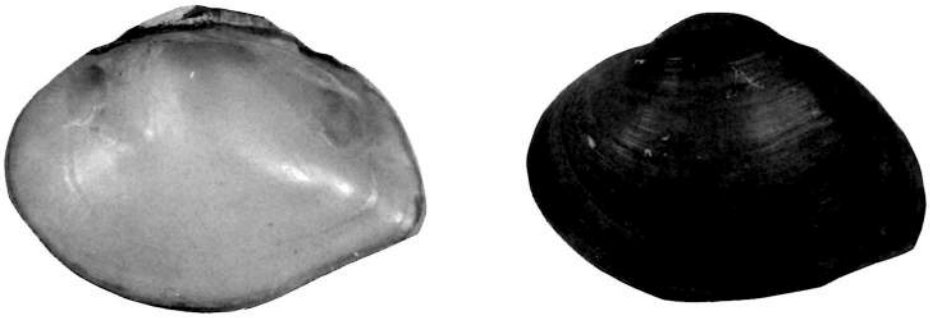
HOSTS: Gizzard shad (Dorosoma cepedianum), flathead catfish (Pylodictis olivaris), white crappie (Pomoxis annularis), black crappie (P. nigromaculatus), and yellow perch (Perca flavescens) (Fuller 1978).

ECONOMIC IMPORTANCE: Usually none; this species is occasionally taken elsewhere for mother-of-pearl and novelties (Murray and Leonard 1962); no harvest reported in Texas.

COMMENTS: The questionable past and present status of this species in Texas is further confounded by the fact that some unionid mussels, including "Elliptio" have been imported through the ornamental fish trade for use in goldfish (Carassius auratus) ponds. Three exotic gastropods and a variety of aquatic plants presumably entered the San Marcos River from aquarium fish sources; reports of spike might reflect similar introductions.



TEXAS PIGTOE
Fusconaia askewi



Texas pigtoe (Fusconaia askewi): West Fork San Jacinto River, Montgomery County, Texas, June 1967; 57 mm shell length; HMNS.

OTHER COMMON NAMES: Pigtoe, Askew's pigtoe.

SYNONYMY: (Simpson 1914, Strecker 1931; Valentine and Stansbery 1971).
Unio askewi Marsh 1896
Quadrula askewi, Simpson 1900
Fusconaia askewi, Valentine and Stansbery 1971

DISTRIBUTION: Reported from the Brazos, Neches, Sabine, and San Jacinto rivers.

DESCRIPTION: (Simpson 1914; Valentine and Stansbery 1971).

Size: To 70 mm in shell length and 47 mm in height in Texas (Simpson 1914); also reported as 95 x 85 mm in Oklahoma (Valentine and Stansbery 1971).

Shell: Generally rhomboidal in shape to almost egg-shaped; inflated; valves nearly equilateral; solid; rounded anteriorly, ventrally slightly indented before the posterior ridge, curved dorsally, posteriorly broadly rounded to nearly truncated; beaks full and high, beak cavities moderate in depth; posterior ridge full and angled dorsally to nearly absent; exterior surface somewhat concentrically sculptured.

Shell Teeth: Two left and one right pseudocardinal teeth triangular and ragged; single right pseudocardinal tooth extends halfway into adductor muscle scar, and with a well-developed ridge posteriorly; lateral teeth curved.

External Color: Dull reddish-brown, dark brown to pale tan with few to many narrow darker rays; eroded portions may appear pink rather than white.

Internal Color: White, pink, or salmon; if pinkish, then color confined exterior to the pallial line.

Soft Tissues: Red ova carried in both inner and outer gills.

HABITAT: Texas pigtoe was collected in the Sabine River in mixed mud, sand, and fine gravel in protected areas associated with fallen trees or other structures [RGH].

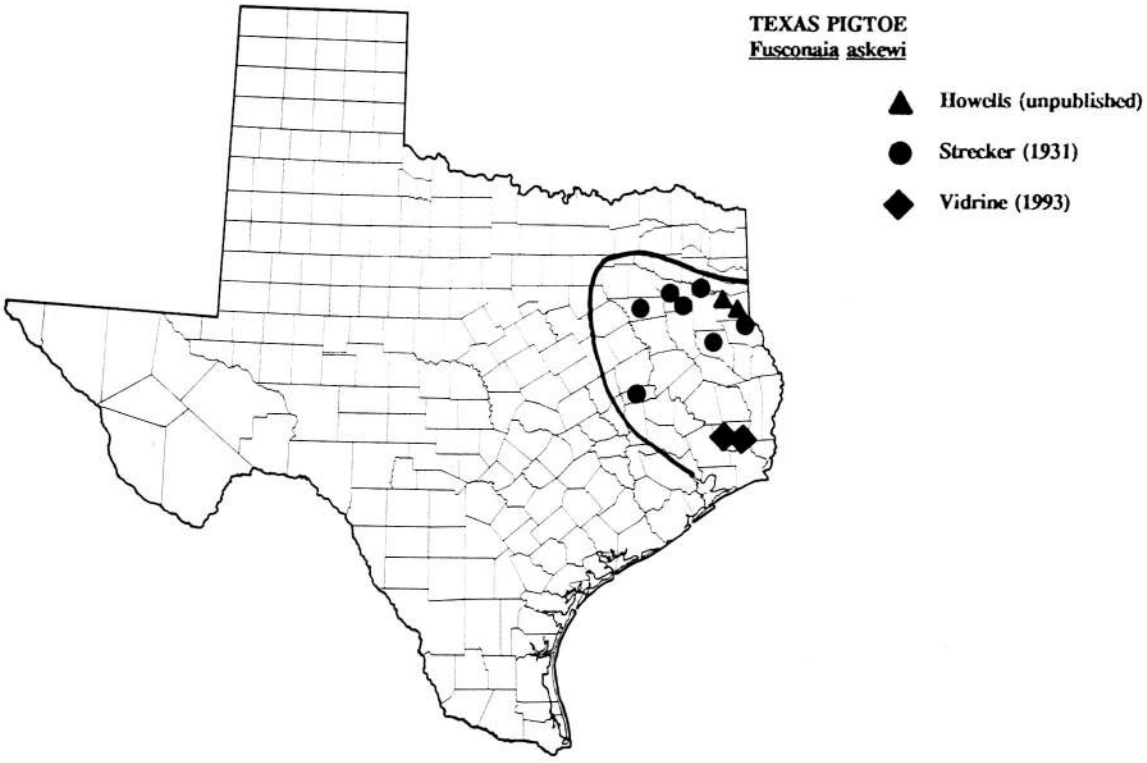
SPAWNING: Glochidia were present in specimens from the Sabine River in July [RGH].

GLOCHIDIA: Small, spineless, elongate-D in shape, 0.144-0.149 mm in shell height, 0.128-0.131 mm in shell length, and 0.123-0.128 mm along the straight hinge line [RGH].

HOSTS: Unreported.

ECONOMIC IMPORTANCE: None reported. Other pigtoes (Fusconaia spp.) were historically taken by the button industry, and some are now harvested for use in the cultured pearl industry; however, there is no confirmation that Texas pigtoe is taken extensively for this purpose.

COMMENTS: Neck (1984) reported Texas pigtoe as locally common, but noted status over its entire range was unclear. Simpson (1914) indicated this species was closely related to triangle pigtoe (F. lananensis). The American Fisheries Society considers this species to be of special concern (Williams et al. 1993).



WABASH PIGTOE
Fusconaia flava

Wabash pigtoe (Fusconaia flava): Little Cypress Bayou, Marion County, Texas, August 1984; 47 mm shell length; HMNS.

OTHER COMMON NAMES: Pigtoe, sheeps nose.

SYNONYMY: (Murray and Leonard 1962; Oesch 1984; Vidrine 1993).

Obliquaria flava Rafinesque 1820
Unio rubiginosa Lea 1829
Unio trigonus Lea 1831
Unio cerinus Conrad 1838
Unio chunii Lea 1861
Unio rubiginosa, Call 1885
Quadrula undata chunii (Lea 1861)
Quadrula rubiginosa Baker 1898
Quadrula flava (Rafinesque 1820)
Fusconaia flava Ortmann 1919

Reports of Gulf pigtoe (F. cerina) in Texas now appear to refer to this species. Vidrine (1993) indicated gulf pigtoe largely occurs in Gulf of Mexico drainages east of the Mississippi River.

DISTRIBUTION: Reported from the Red, Sabine, Neches, Trinity and San Jacinto rivers.

DESCRIPTION: (Simpson 1914; Murray and Leonard 1962; Oesch 1984; Cummings and Mayer 1992; Vidrine 1993).

Size: To at least 78 mm shell length and 56 mm shell height (Simpson 1914); also reported to 76 mm in length in the northcentral states (Cummings and Mayer 1992), 95 mm in length in Missouri (Oesch 1984), and 114 mm in length in Kansas (Murray and Leonard 1962).

Shell: Shape variable but often broadly to sharply triangular or elongate-quadrate; inflated (large rivers) to compressed (smaller streams); moderately thick, occasionally thin; solid to sub-solid; rounded anteriorly and ventrally, posteriorly truncated and blunt pointed, dorsally straight to slightly curved; beaks low to elevated, inflated and turned forward, beak cavities deep; posterior ridge well developed and prominent; wide, shallow sulcus in advance of posterior ridge; surface with a cloth-like appearance to epidermis.

Shell Teeth: Two left pseudocardinal teeth triangular, rough, serrate, and elongated; single right pseudocardinal tooth large, biangular, and elevated, often with an anterior denticle; lateral teeth two left and one right,

straight or slightly curved, occasionally a second, weak lateral tooth present in the right valve.

External Color: Yellowish-brown in juveniles to chestnut or dark brown in adults; occasionally with green rays.

Internal Color: Usually white, occasionally with a salmon or yellow tint; iridescent posteriorly.

Soft Tissues: Often yellowish-orange; non-gravid gills brown, but red, pink, or white with conglutinates.

HABITAT: This pigtoe has been reported from creeks to large rivers on mud, sand, and gravel (Cummings and Mayer 1992); from all habitats except deep, shifting sands; and at depths of 7.6 cm to 1.2-1.5 m (Murray and Leonard 1962); in moderate to swift current velocities (Harris and Gordon undated). Metcalf (1980) observed Wabash pigtoe was especially intolerant of changing stream environments.

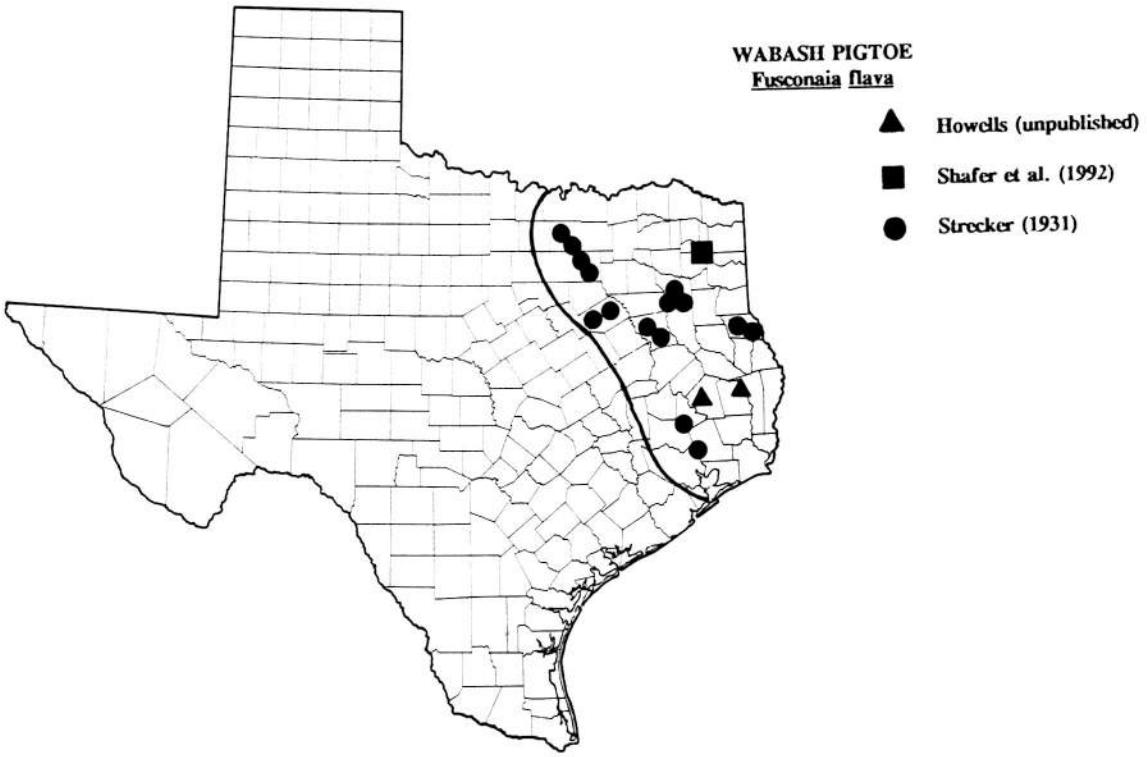
SPAWNING: Wabash pigtoe is a short-term, tachytictic breeder reproducing from May to August (Baker 1928).

GLOCHIDIA: Shell small, spineless, and semi-circular with a nearly straight hinge line, 0.150 x 0.155 mm (Utterback 1915-16).

HOSTS: Bluegill (Lepomis macrochirus), white crappie (Pomoxis annularis), and black crappie (P. nigromaculatus) (Fuller 1978).

ECONOMIC IMPORTANCE: Wabash pigtoe was once important for shell buttons and large specimens are occasionally taken now for the cultured pearl industry; however, there is probably limited commercial harvest in Texas at this time.

COMMENTS: Surveys by TPWD 1992 and through mid-1994 failed to collect this species either alive or as recently-dead shell [RGH].



TRIANGLE PIGTOE
Fusconaia lananensis

Triangle pigtoe (Fusconaia lananensis): Village Creek, Hardin County, Texas, October 1969; 58 mm shell length; HMNS.

OTHER COMMON NAMES: Pigtoe, Lanana pigtoe.

SYNONYMY: (Simpson 1914; Strecker 1931).
Quadrula lananensis Frierson 1901
Fusconaia lananensis, Ortmann 1901

DISTRIBUTION: Reported from the Neches and San Jacinto rivers (Strecker 1931); also from Village Creek, Hardin County (Vidrine 1990). Type locality Lanana and Bonita creeks near Nacogdoches, Nacogdoches County, Texas (Simpson 1914).

DESCRIPTION: (Simpson 1914; Strecker 1931).

Size: To at least 81.3 mm shell length and 58.4 in shell height (Simpson 1914).

Shell: Shape quadrate to triangular; valves nearly equilateral; moderately thick, but thinner posteriorly; rounded anteriorly, rounded anterio-ventrally but otherwise straight ventrally, curved dorsally, posteriorly broadly curved, oblique to triangular; beaks eroded, low, and slightly inflated, beak cavities deep and full; posterior ridge angular over beaks, but ill-defined ventrally; pallial line distinct anteriorly but obscure posteriorly; dorsally shell smooth and polished but striated ventrally and on the posterior slope; usually displays unique pearly "studs" internally on the shell.

Shell Teeth: Pseudocardinal teeth stumpy, double in the left valve and single in the right; lateral teeth thin and nearly straight.

External Color: Reddish-brown, slightly olive tinted; may show obscure rays; ligament brown in color and smooth.

Internal Color: Rose with blotches of yellow surrounded by brown.

Soft Tissues: Off-white to tan; gravid gills pinkish-orange [RGH].

HABITAT: This species was found in Attoyac Bayou in mixed mud, sand, and fine gravel [RGH].

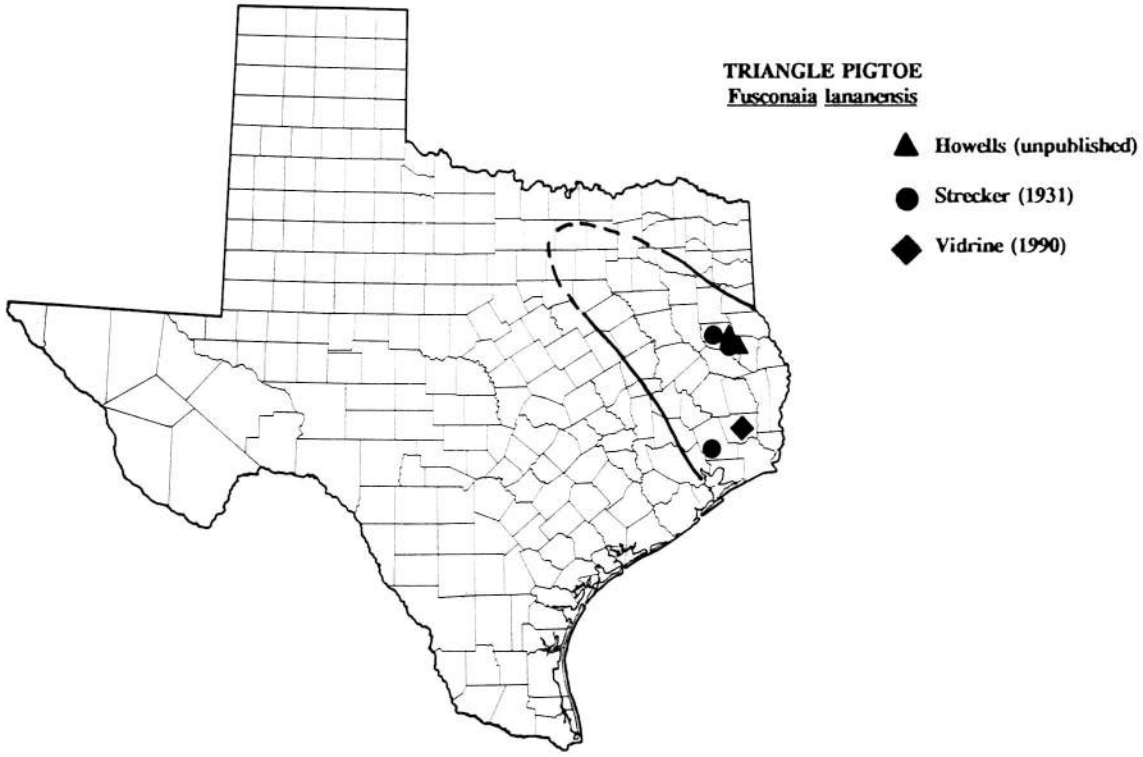
SPAWNING: Developing eggs were present in marsupia of females from Attoyac Bayou in July [RGH].

GLOCHIDIA: Unreported.

HOSTS: Unreported.

ECONOMIC IMPORTANCE: None reported. Triangle pigtoe may be taken by musselers harvesting Wabash pigtoe, but small size and general rarity probably limit commercial importance.

COMMENTS: Athearn (1970) listed triangle pigtoe as rare and/or endangered; however, neither the U.S. Fish and Wildlife Service nor TPWD presently list it. Texas pigtoe (F. askewi) is similar, but longer, more compressed, oblique, never as inflated, never as thick anteriorly, and never shows the pearly bumps typical of triangle pigtoe (Simpson 1914). Triangle pigtoe is closely related to Texas pigtoe (Simpson 1914). The American Fisheries Society considers this species of special concern (Williams et al. 1993).



ROUND PEARLSHELL
Glebula rotundata

Round pearlshell (Glebula rotundata): Buffalo Bayou, Harris County, Texas, July 1969; 65 mm shell length; TUC.

OTHER COMMON NAMES: None.

SYNONYMY: (Simpson 1914; Strecker 1931).

Unio suborbiculata Lamarck 1819
Unio glebulus Say 1831
Unio suborbiculatus Ferrussac 1835
Margarita rotundatus Lea 1836
Unio subglobosus Lea 1834
Unio rotundatus, Hanley 1843
Margaron rotundatus, Lea 1852
Glebula rotundata, Conrad 1853

DISTRIBUTION: Typically occurs from the San Jacinto River and Buffalo Bayou into drainages to the north and east; Strecker (1931) discussed a population in Calhoun County, Texas, farther west in the Guadalupe River drainage. Simpson (1914) discussed an earlier report by Conrad (1855, Proc. Acad. Natural Sci. Phila., VII.) of this, or a similar species from the Rio Grande, much farther west than other reports: however, this may have been a misidentified Tampico pearlymussel (Cyrtonaias tampicoensis).

DESCRIPTION: (Burch 1973; Clench 1959; Simpson 1914; RGH).

Size: Reported as 95 mm shell length and 72 mm in shell height (Simpson 1914), and to 150 mm in shell length (Parker et al. 1984).

Shell: Shape elliptical, rounded, globular; inflated, females slightly more inflated ventrally; rather solid; dorsal margin curved (sometimes straight for a distance behind the beak, curved anteriorly and ventrally, posteriorly curved but somewhat pointed; beaks flattened or compressed but fuller in older specimens, smooth, beak cavities shallow; posterior ridge moderately developed, angular, occasionally slightly double; posterior shell smooth or with radiating lines; with a cloth-like appearance.

Shell Teeth: Left two pseudocardinal teeth small, split into radiating nodular lamellae; two right pseudocardinal teeth with the uppermost small and compressed and the lower split into multiple lamellae; left lateral teeth double, short, low, with the lower tooth longer; right valve laterals usually singular, but sometimes slightly double; split nodular lamellae on pseudocardinal teeth are unlike those of other American unionids.

External Color: Dark brown to nearly black, reported as ashy-gray in some; dull.

Internal Color: Dull purple or white; sometimes slightly iridescent.

Soft Tissues: Marsupia reported in posterior portions of outer gills.

HABITAT: It was reported by Parker et al. (1984) from slow-flow bayou habitats, usually within 30 m of shore, and within the following physicochemical parameters: total alkalinity 35-230 mg/liter ($CaCO_3$), dissolved oxygen 4.5-17.4 mg/liter, pH 6.0-9.3, conductivity 49-480 μmohos, 7.0-33.5° C, and occasionally in low-salinity, estuarine habitats with Atlantic rangia (Rangia cuneata).

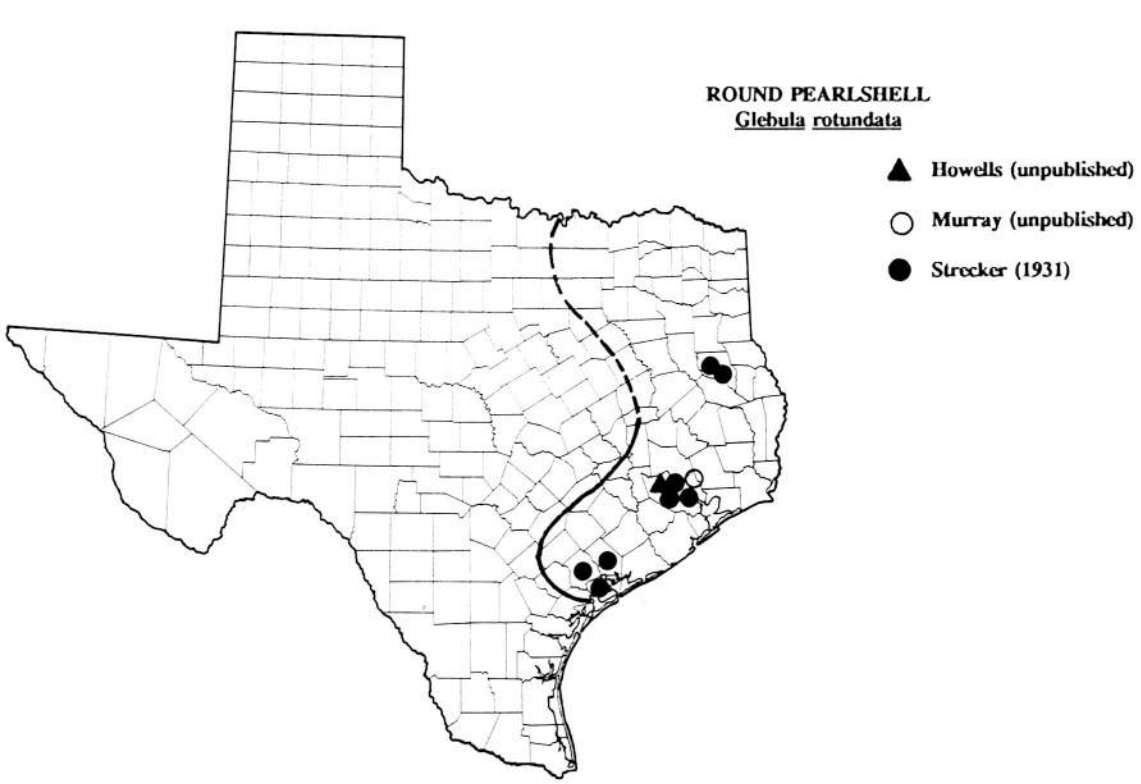
SPAWNING: Marsupia have been reported barren late fall through winter; females become ovigerous in March (corresponding to rapid increases in water temperature) continuing through September, with glochidia present March through October (Parker et al. 1984). Additionally, Parker et al. (1984) indicated there may be three periods of production and release of glochidia during the spawning season and that females 93.5-119.3 mm shell length held and average of 531,000 glochidia.

GLOCHIDIA: Depressed elliptical, with evenly-curved margins, hinge line straight, 0.165-0.170 mm shell length, 0.320-0.325 mm shell height, and 0.135-0.137 mm along the hinge line [RGH].

HOSTS: Found on gills of field-collected spotted gar (Lepisosteus oculatus), common carp (Cyprinus carpio), and white bass (Morone chrysops), as well as the estuarine species bay anchovy (Anchoa mitchilli) and hogchoker (Trinectes maculatus), also successfully attached and transformed on both gills and fins of green sunfish (Lepomis cyanellus) and bluegill (L. macrochirus) in laboratory studies (Parker et al. 1984).

ECONOMIC IMPORTANCE: None. Although listed as a pearl-producing species (Kunz 1897), round pearlshell is apparently not harvested in Texas for this reason.

COMMENTS: Strecker (1931) reported specimens from Green Lake, Calhoun County, Texas, twice as large as other examples and with a smooth, ashy-white epidermis.



TEXAS FATMUCKET
Lampsilis bracteata

Texas fatmucket (Lampsilis bracteata): Left (both) Pedernales River, Gillespie County, Texas, June 1992; 55 mm shell length; TPWD. Center and right Elm Creek, Runnels Couunty, Texas, August 1993; center (both) 70 mm, right (both) 56 mm; TPWD.

OTHER COMMON NAMES: Fatmucket.

SYNONYMY: (Strecker 1931, Burch 1973).
Unio bracteatus Gould 1855
Unio rowellii Singley, Strecker 1931

DISTRIBUTION: Occurs in the San Antonio, Guadalupe, and Colorado river systems; Colorado River populations occur at least as far west as Concho River tributaries in Tom Green County [RWN].

DESCRIPTION: (Burch 1973; RGH).

Size: Shell to at least 90 x 53 mm in Texas [RGH]; given by Burch (1973) as up to 75 mm long.

Shell: Rhomboidal (oval in females), sometimes slightly elongate; sub-solid to solid; not especially thick; rounded anteriorly, ventrally gently rounded to nearly straight, dorsally slightly rounded, broadly rounded posteriorly to nearly obliquely truncated; beaks above hinge line, beak cavities moderate in depth; posterior ridge weak and ill defined; exteriorly smooth except for growth rings. Note some populations show a "riffle" morph which is decidedly more elongate [RWN].

Shell Teeth: Two left pseudocardinal teeth both triangular and compressed; posterior tooth ranges from elevated and rough edged to reduced or nearly absent; anterior tooth elevated, often rough, slightly striate; two right pseudocardinal teeth (or one tooth and a denticle), anterior tooth small, barely above hinge line, compressed; posterior tooth elevated, compressed, triangular to nearly quadrate, rough edged; left lateral teeth two, elongate, compressed, nearly straight or slightly curved, ventral-most tooth higher; one right lateral tooth, long, compressed, highest posteriorly, vaguely striate.

External Color: Tan to brown; continuous rays of dark brown, green-brown or black; beaks often lighter, sometimes not rayed; distance between rays is similar both posteriorly and ventrally, rays often wider ventrally than dorsally.

Internal Color: Pearly white, some with a light salmon tint.

Soft Tissues: Foot and mantle tan, mantle edges gray to black; gravid gills dark tan with outer third black; females with fish-like mantle flap, gray with a black, white- or gold-ringed eye spot dorsally and filament-like mantle extensions below the mantle flap [RGH].

HABITAT: It occurs in streams and rivers on sand, mud, and gravel [RGH]. Subfossil shells taken from the Llano and San Saba rivers suggest association with broken bedrock and course gravel or sand in moderately flowing waters. It was found in a Colorado River tributary between bedrock slabs where it moves as far inward as shell size will allow [RGH].

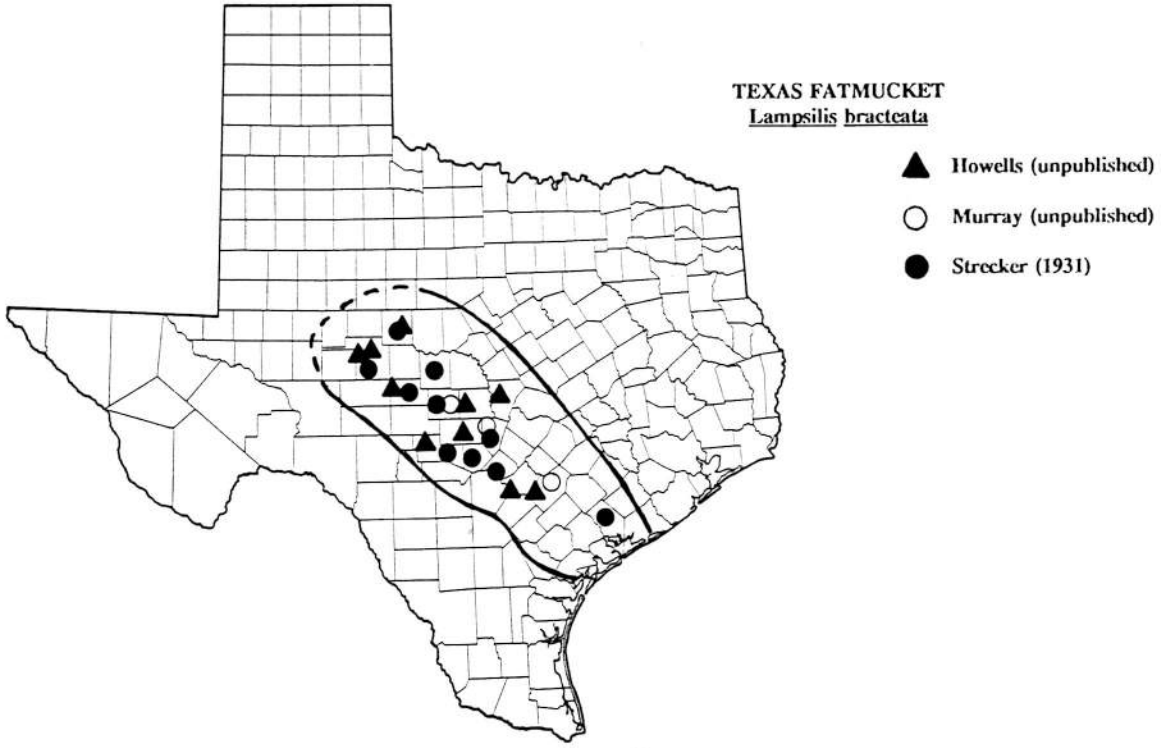
SPAWNING: Females with glochidia have been taken in Runnels County August and early September [RGH]. Captive females displayed fish-like mantle flaps and vigorously waved them, sometimes increasing activity in response to shadows passing over the holding tank. Captive females produced white, spindle-shaped conglutinate masses containing glochidia 12 days after capture and placement in laboratory tanks [RGH].

GLOCHIDIA: Shells moderately large, subelliptical, spineless, 0.262-0.270 mm shell height, 0.213-0.230 mm shell length, 0.123-0.131 mm along the hinge line, gently curved ventrally [RGH].

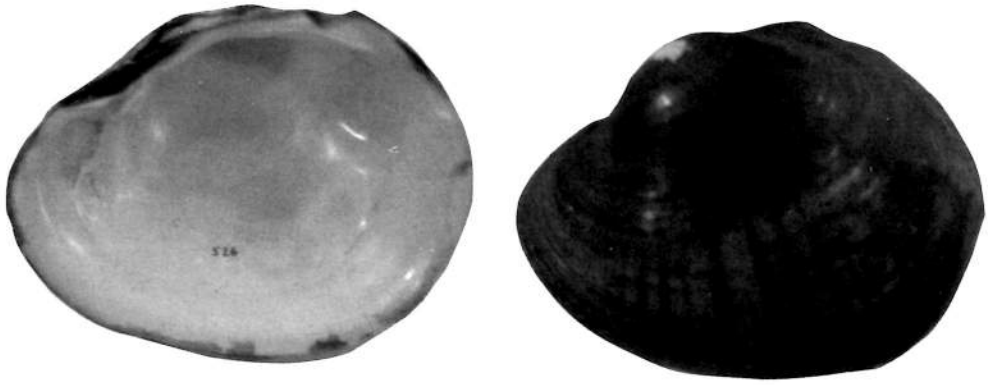
HOSTS: Laboratory infections were successfully induced in bluegill (Lepomis macrochirus) and green sunfish (L. cyanellus), but not in longear sunfish (L. megalotis), blacktail shiner (Cyprinella venusta), or goldfish (Carassius auratus) [RGH].

ECONOMIC IMPORTANCE: None.

COMMENTS: Strecker (1931) indicated records of L. luteola from Texas referred to L. bracteata (though some may have represented Louisiana fatmucket (L. hydiana) or sandbank pocketbook (L. satura), as well). Reports of speckled pocketbook (L. streckeri) from Onion Creek, Travis County, and Salado Creek, Bell County, (Strecker 1931) are believed to be based upon atypical specimens of Texas fatmucket (see discussion in Neck 1984). Speckled pocketbook is apparently similar to Texas fatmucket but with rays broken by colorless rings (Burch 1973); though a valid species, speckled pocketbook is not present in Texas [RWN]. Examination of Onion Creek by TPWD in 1993 found no living unionids of any species [RGH]. The American Fisheries Society considers Texas fatmucket of special concern (Williams et al. 1993).



PLAIN POCKETBOOK
Lampsilis cardium



Plain pocketbook (Lampsilis cardium): Mountain Fork River, Oklahoma, April 1972; 75 mm shell length; TUC.

OTHER COMMON NAMES: Pocketbook mussel, grandmaw.

SYNONYMY: (Murray and Leonard 1962; Vidrine 1993).

Unio cardium Rafinesque 1820
Unio ventricosa Barnes 1823
Unio occidens, Call 1885
Lampsilis ovata ventricosa, Ortmann 1919

This species has also been confused with pocketbook (L. ovata), southern pocketbook (L. ornata), and sandbank pocketbook (L. satura). Synonymy is confused.

DISTRIBUTION: Red River [RWN]. Specimens identified as pocketbooks (L. ovata) reported from the Big Cypress Bayou above Caddo Lake (Shafer et al. 1992) may be this species.

DESCRIPTION: (Murray and Leonard 1962; Cummings and Mayer 1992; Vidrine 1993; Harris and Gordon undated).

Size: Reported to 178 mm in shell length in the northcentral states (Cummings and Mayer 1992), 152 mm in Kansas (Murray and Leonard 1962), and to approximately 203 mm in Arkansas (Harris and Gordon undated).

Shell: Oval to nearly quadrate; fragile and thin to thick and solid; inflated, females often more inflated; rounded anteriorly, obscurely round-pointed posteriorly (more bluntly truncated in females), dorsally nearly straight to slightly rounded, ventrally broadly rounded to straight; beaks high and turned forward, beak cavities deep; posterior ridge broadly rounded; more defined than in Louisiana fatmucket (L. hydiana) or Texas fatmucket (L. bracteata), and shell less elongate; growth lines may or may not be prominent exteriorly on shell.

Shell Teeth: Two left and one right pseudocardinal teeth large, elevated, somewhat compressed, rough in young but rounded in adults, posterior left pseudocardinal tooth high and triangular, anterior left pseudocardinal tooth smaller; lateral teeth rather short to moderately long, striated.

External Color: Yellow or yellowish-green to tan with green or brown rays; typically glossy.

Internal Color: White to bluish-white, occasionally pink; pearly posteriorly.

Soft Tissues: Possesses a fish-like mantle extension which is moved actively to simulate a small fish.

HABITAT: It has been found in small creeks and large rivers, often in flowing waters, occasionally in oxbows or slackwater areas of sandy-bottomed rivers, occasionally in reservoirs; it occurs on sand, sand-gravel, or sand-mud, but not typically in dense beds (Cummings and Mayer 1992; Harris and Gordon undated). It has been reported from depths of several cm to 1.2 m (Murray and Leonard 1962).

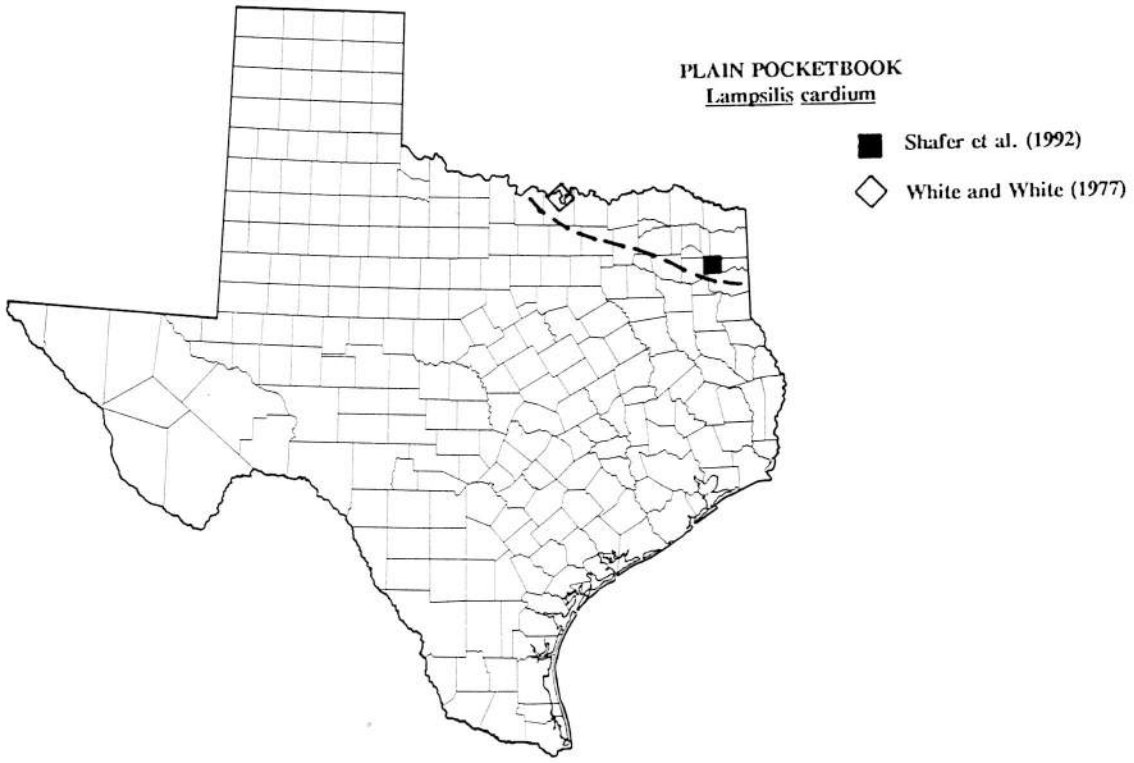
SPAWNING: It is a long-term breeder carrying glochidia from August through early July (Harris and Gordon undated). Holland-Bartels and Kammer (1989) reported eggs in plain pocketbooks in the upper Mississippi River began maturing as water temperatures increased from 20° C to 25° C, fertilization occurred from late July through mid-August, embryos were produced by mid-August after river temperatures peaked and were declining, and glochidia were held over winter and released late May and June (peak) as water temperatures increased.

GLOCHIDIA: Unreported.

HOSTS: White crappie (Pomoxis annularis) and sauger (Stizostedion canadense) (Baker 1928); smallmouth bass (Micropterus dolomieu) and bluegill (Lepomis macrochirus) (Harris and Gordon undated).

ECONOMIC IMPORTANCE: It usually has no economic importance due to shell thinness and chalky nature.

COMMENTS: The species is not well known in Texas. Earlier listings of this species throughout much of eastern Texas may reflect confusion with sandbank pocketbook (L. satura). The American Fisheries Society considers the plain pocketbook of special concern (Williams et al. 1993).



LOUISIANA FATMUCKET
Lampsilis hydiana

Louisiana fatmucket (Lampsilis hydiana): Left and right B.A. Steinhagen Reservoir, Tyler County, Texas, May 1993; left (both) 75 mm shell length, top right 75 mm, bottom right 58 mm; TPWD. Center Lake Gonzales, Gonzales County, Texas, August 1992; top center 79 mm, bottom center 91 mm; TPWD.

OTHER COMMON NAMES: Fatmucket, grass mucket.

SYNONYMY: (Strecker 1931; Murray and Roy 1968; Burch 1973).

Unio hydianus Lea 1838
Unio approximus Lea 1845
Lampsilis fasciata hydiana Lea 1838, Strecker 1931
Lampsilis hydiana (Lea 1838), Simpson 1900

DISTRIBUTION: Occurs from the San Antonio River into other systems to the north and east. Murray (1978) reported this species from Lake Corpus Christi in the Nueces River system.

DESCRIPTION: (Burch 1973; Harris and Gordon undated; RGH).

Size: To at least 95 mm in shell length in Texas [RGH]; reported to about 127 mm in Arkansas and Burch (1973) listed the species as greater than 100 mm.

Shell: Rhomboidal, to nearly oval in some females; broadly rounded anteriorly, rounded in males to somewhat truncated in females posteriorly, slightly curved dorsally, ventrally nearly straight to slightly concave centrally in some; females swollen posterio-ventrally; beaks raised above hinge line, beak cavities moderately deep; posterior ridge weak and broadly rounded; shell smooth and unsculptured except for growth rings.

Shell Teeth: Two left pseudocardinal teeth with the anterior tooth triangular to columnar, compressed, erect, and lightly striated, posterior tooth smaller, triangular to rounded at the tip, weakly striated [one male examined lacked this posterior tooth]; two right pseudocardinal teeth (or one tooth and one anterior denticle) rectangular to subrectangular, strongly compressed, very slightly striated, emarginate, and pointed to round-pointed; lateral teeth moderately long, compressed, leaf-like, and striated diagonally or not.

External Color: Tan to brown with relatively thin green (sometimes bright green), brown, or black rays over entire shell; some specimens may be evenly colored (dark or light) with only very vague indication of fine, faint rays, or may be rayless; distance between rays is often greater posteriorly than ventrally.

Internal Color: Pearly white.

Soft Tissues: White to tan; gills and foot slightly darker; gravid gills milky-white with a distinctive black edge ventrally and posteriorly [RGH].

HABITAT: It may be found in rivers, streams, and reservoirs; it is sometimes taken in mud or mud and sand in low-flow situations [RGH]. Harris and Gordon (undated) reported Louisiana fatmucket from medium to large rivers, slow-flow or backwater areas, and on rock, gravel, gravel-sand, and mud.

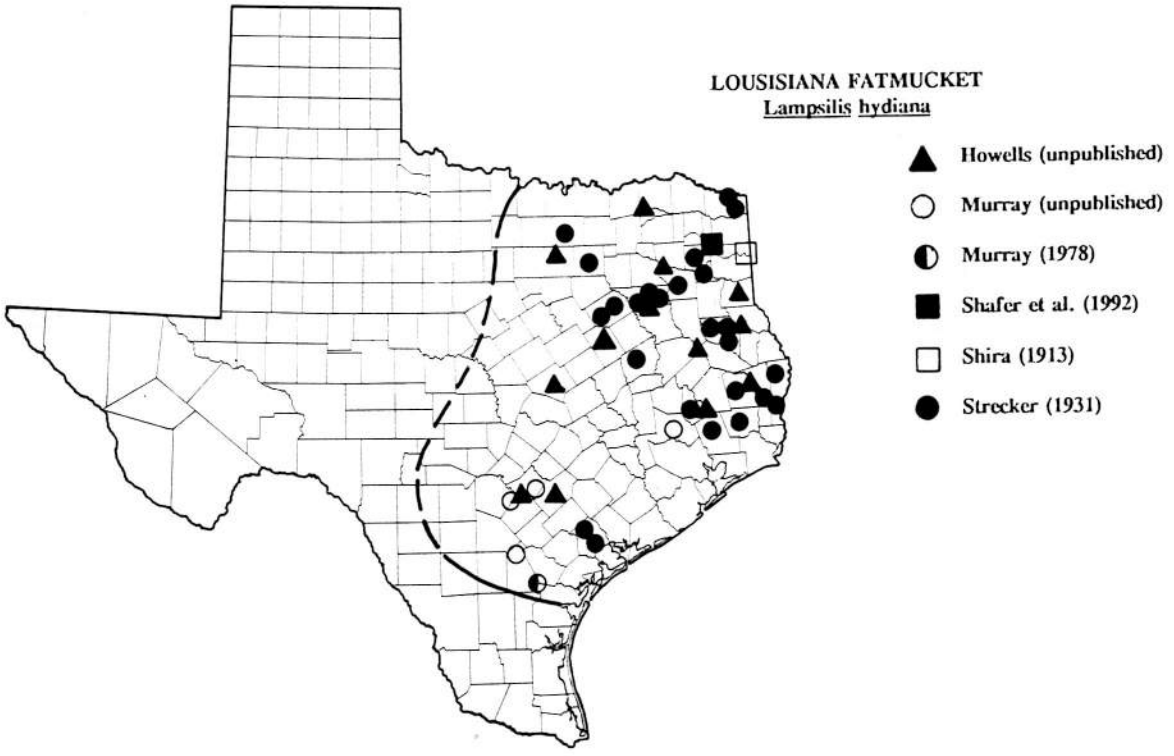
SPAWNING: Females were taken with mature eggs in late August in central Texas, and with glochidia in late May and June in southeastern Texas [RGH]; it has been considered a long-term breeder (Harris and Gordon undated).

GLOCHIDIA: Shell is medium sized, 0.269 x 0.218 mm, hinge line relatively straight and 0.103 mm long, broadly spatulate in shape [RGH].

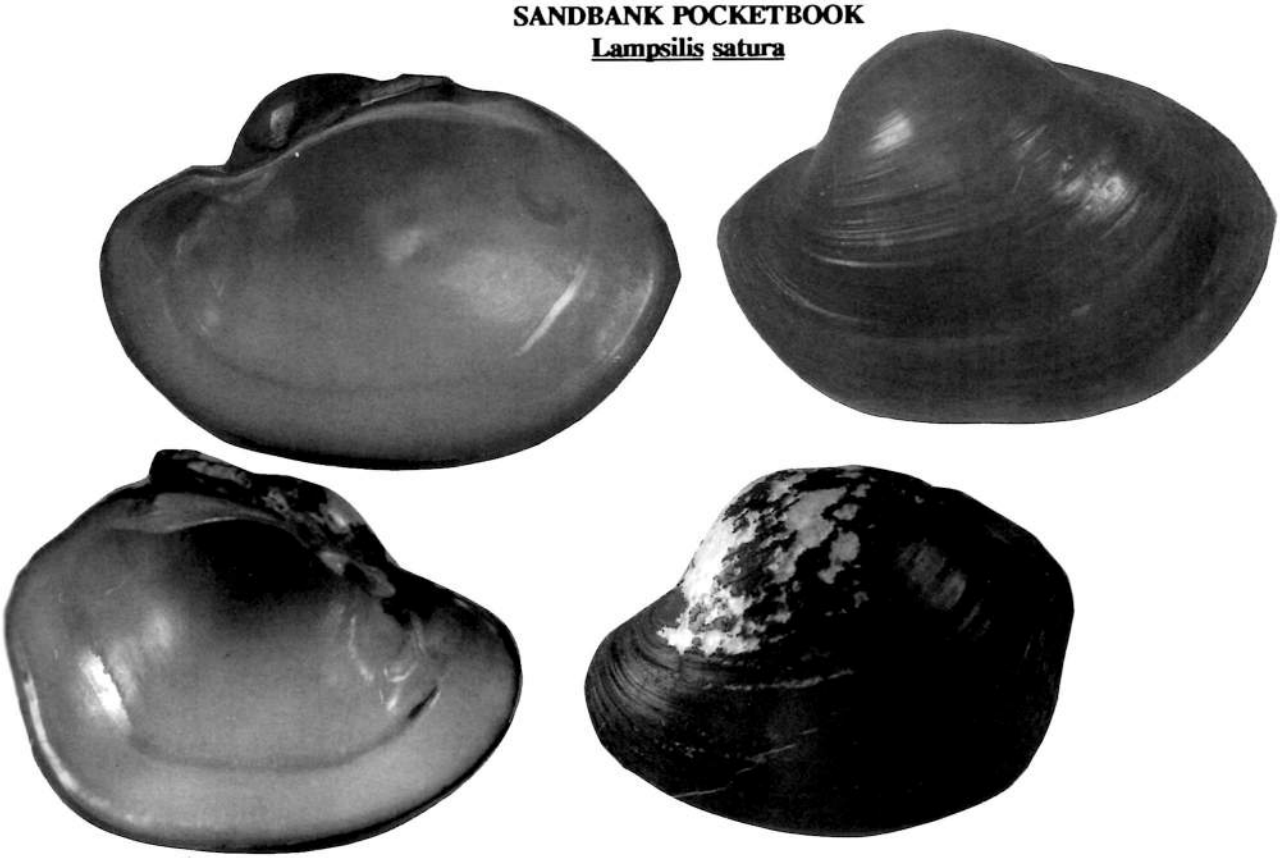
HOSTS: Unreported. Glochidia appeared to attach successfully to longear sunfish (Lepomis megalotis) in the laboratory but were not followed through transformation to the juvenile stage; Texas shiner (Notropis amabilis), blacktail shiner (Cyprinella venusta), channel catfish (Ictalurus punctatus), blue catfish (I. furcatus), and greenthroat darter (Etheostoma lepidum) were not acceptable hosts [RGH].

ECONOMIC IMPORTANCE: None.

COMMENTS: This species is usually larger, heavier-shelled, and more inflated than Texas fatmucket (L. bracteata).



SANDBANK POCKETBOOK
Lampsilis satura



Sandbank pocketbook (Lampsilis satura): Top Neches River, Jasper County, Texas, May 1993; 103 mm shell length; TPWD. Bottom Sabine River, Panola County, Texas, July 1994; 97 mm; TPWD.

OTHER COMMON NAMES: Grandmaw, white bleufer, white pocketbook.

SYNONYMY: (Strecker 1931; Vidrine 1993).

Unio satur Lea 1852
Lampsilis cardium satura (Lea 1852)
Lampsilis ventricosa var. satura (Lea 1852), Simpson 1914
Lampsilis ovata ventricosa (Barnes 1823)
Lampsilis ventricosa satura Lea, Scammon 1906
Lampsilis satura (Lea)

DISTRIBUTION: Occurs from the San Jacinto River north and east.

DESCRIPTION: (Murray and Leonard 1962; Valentine and Stansbery 1971; Vidrine 1993; Harris and Gordon undated; RGH).

Size: To at least 103 mm shell length in Texas [RGH]; also reported to about 152 mm in Arkansas (Harris and Gordon undated).

Shell: Suboval; inflated to greatly inflated in females (marsupial swellings very prominent); moderately thick; anteriorly shallow dorso-ventrally, but posteriorly very deep dorso-ventrally; dorsal margin curved posteriorly, little curved anteriorly, posteriorly almost truncated (slightly indented in larger specimens) to

rounded, ventrally slightly curved to nearly straight (sometimes slightly concave at mid-body); beaks raised high above hinge line, beak cavities deep; posterior ridge broadly rounded; externally relatively smooth except for fine, concentric growth lines.

Shell Teeth: Pseudocardinal teeth two left and one right relatively thin and leaf-like but well developed; dorsal pseudocardinal tooth low and elongate, not strongly projecting above the anterior tip of the valve; lateral teeth moderately long and high.

External Color: Deep chestnut-brown, smoky-gray to black, lighter yellow-brown on beaks; paler peripherally; with green rays or rayless to nearly so; glossy.

Internal Color: Pearly white.

Soft Tissues: Tan.

HABITAT: It may occur in small to large rivers with moderate flows on gravel, gravel-sand, and sand bottoms (Harris and Gordon undated). It is present in the Neches River below B.A. Steinhagen Reservoir, Jasper County, Texas, on gravel bottom in swift current at 6.1-6.5-m depths [RGH]. Once somewhat frequently found in pure sand banks of Village Creek, Hardin County, Texas [RWN]; however, collections by TPWD in this area in 1994 found no living unionids.

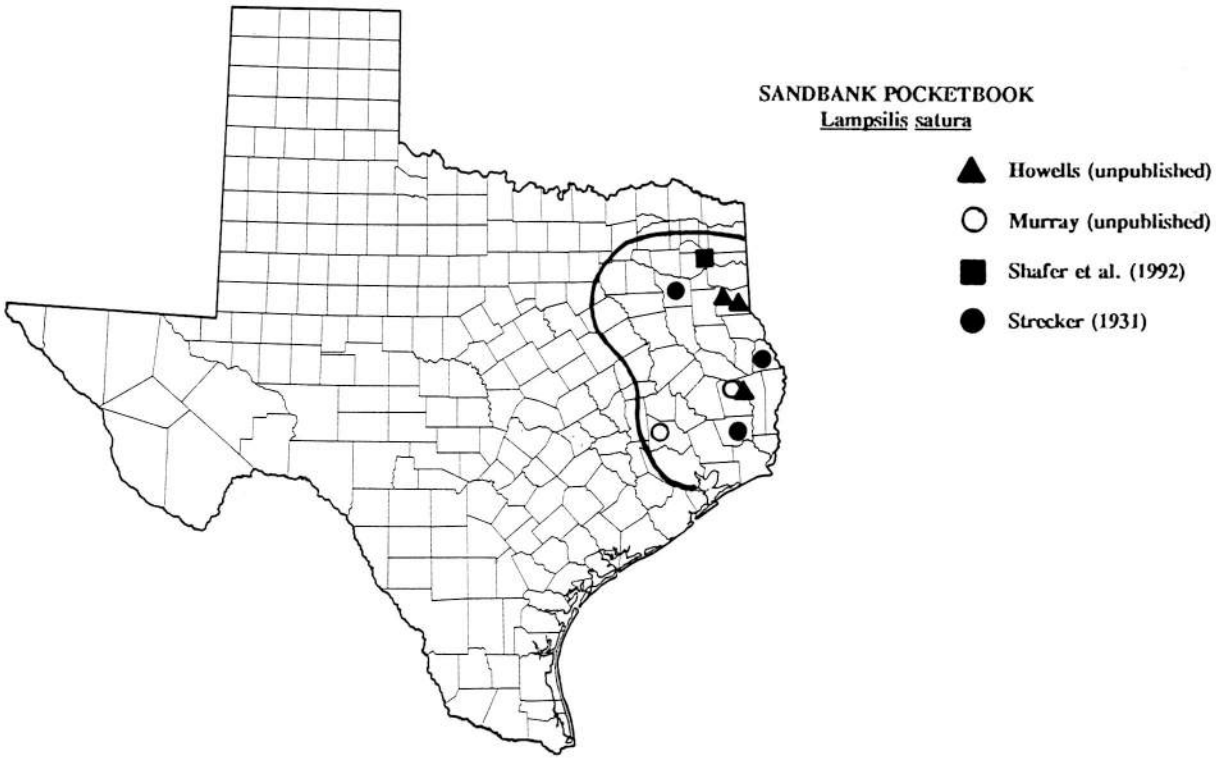
SPAWNING: Unreported.

GLOCHIDIA: Valentine and Stansbery (1971) reported them as semi-elliptical and similar to glochidia of fat pocketbook (Potamilus capax).

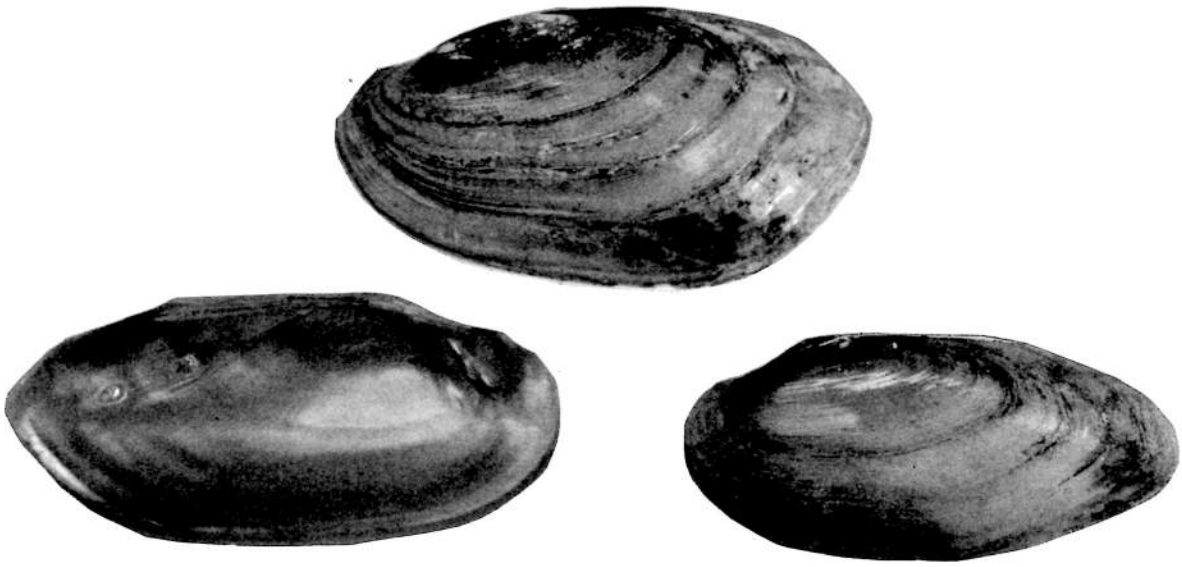
HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

COMMENTS: This species is poorly known in Texas.



YELLOW SANDSHELL
Lampsilis teres



Yellow sandshell (Lampsilis teres): Top Lake Wood, Gonzales County, Texas, July 1992; 129 mm shell length; TPWD. Bottom Choke Canyon Reservoir, Live Oak County, Texas, January 1992; 110 mm; TPWD.

OTHER COMMON NAMES: Thinrhine, creeper, bank creeper, banana, sandshell, sand clam, luster shell, tiger tooth.

SYNONYMY: (Murray and Leonard 1962; Oesch 1984).

Unio teres Rafinesque 1820
Unio anodontoides Lea 1834
Unio teres Rafinesque = U. anodontoides Lea, Conrad 1834
Lampsilis anodontoides Baker 1898
Lampsilis anodontoides (Lea), Simpson 1914
Lampsilis teres (Lea) = U. anodontoides (Raf.), Utterback 1916

Classification of yellow sandshell and a related form called slough sandshell (not present in Texas) has been confused. Recent trends follow use of L. t. anodontoides (Rafinesque 1820) for yellow sandshell and L. t. teres (Smith 1899) for slough sandshell, and reject use of L. fallaciosa (Smith 1899) for either form (see discussion in Oesch 1984).

DISTRIBUTION: All major river systems.

DESCRIPTION: (Murray and Leonard 1962; Oesch 1984; RGH).

Size: To 145 mm in shell length in Texas (Littleton 1979); also reported to 122 mm in Missouri (Oesch 1984); 127 mm in Kansas (Murray and Leonard 1962), 149 x 73 mm in Ohio (Valentine and Stansbery 1971), and 178 mm in Illinois (Haas 1941).

Shell: Oblong and elongate; females often swollen posteriorly; shells relatively thin in smaller, younger specimens, but thicker in older, larger animals, never extremely thick or heavy; dorsal edge relatively straight, anterior margin rounded, posterior margin centrally pointed, ventral margin gently curved to nearly straight;

thickness uniform across most of the shell; beaks moderately raised above hinge line, beak cavities shallow; posterior ridge broad and rounded; often extremely smooth exteriorly except for growth rings.

Shell Teeth: Two left pseudocardinal teeth high, elongate, compressed, and striated; single right posterior pseudocardinal tooth erect, compressed, and striated, and with a long, low, compressed anterior tooth; lateral teeth long, slightly curved, lamellar, and roughened.

External Color: Yellow to straw-colored, tan, brown, or black; becomes darker with age and size; beaks reddish in some specimens; usually unrayed (often rayed in slough sandshell), but occasionally with vague rays; concentric growth lines are often boldly brown or black; often glossy, occasionally dull. Specimens from some areas (e.g., Little Brazos River, Robertson County) may become very dark at relatively small sizes; however, other populations may remain very pale in larger, older animals (e.g., Lake Gonzales, Gonzales County).

Internal Color: Very pearly white, perhaps the most pearly of any freshwater unionid; occasionally bluish-white with cream or salmon tints (Oesch 1984). The bold pearly nature may dull quickly upon death under field conditions.

Soft Tissues: Grayish-white; mantle edge near branchial opening sometimes red; marsupia occupy the posterior half of the outer gills; females with a simple mantle flap, often with an orange stripe; gravid gills milky and sometimes with a black edge ventrally and posteriorly.

HABITAT: The species has been reported from large and small streams and rivers, often in warm water and under turbid conditions and in slow- to fast-flow conditions; it tolerates many bottom types from rock to mud, but avoids deep, shifting sands (Murray and Leonard 1962; Buchanan 1980; Oesch 1984). It has been characterized as intolerant of drought and dewatering (Strecker 1931). Coker et al. (1921) described yellow sandshell as a species which could actively follow flood water on to inundated lands, then retreat as water recedes. It is often found in association with other species rather than in large groups of its own (Coker et al. 1921).

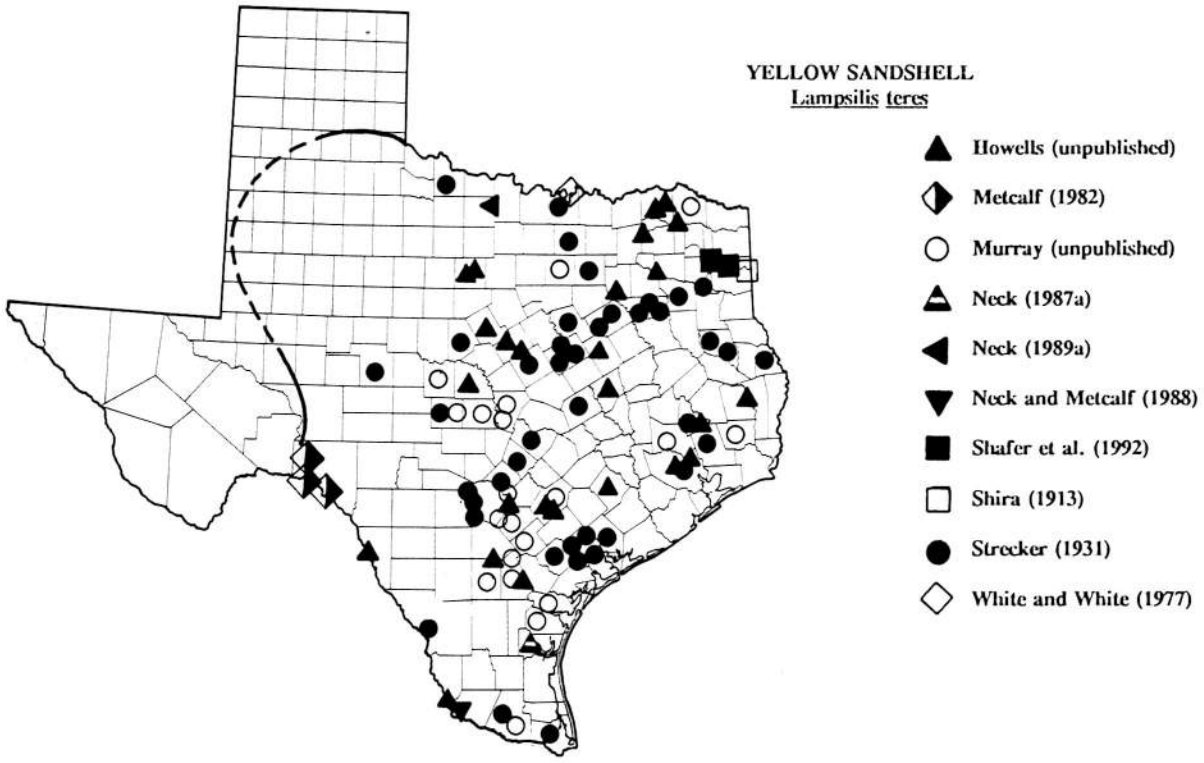
SPAWNING: It was considered a long-term breeder (bradytictic) by Baker (1928); Texas specimens have been found with glochidia in June and August (Littleton 1979), and May through July in central Texas and October and November in southern Texas [RGH]. Hoggarth (1988) noted glochidia in March and April. Valentine and Stansbery (1971) indicated surprisingly small, gravid females sometimes occur. The smallest mature female reported by Littleton (1979) from the Navasota River, Texas, was 53 mm shell length.

GLOCHIDIA: Shells medium-sized, subelliptical, spineless, hinge line stout and evenly curved, 0.185 x 0.210 (Utterback 1915-16). Hoggarth (1988) described glochidia as subspatulate, 0.187-0.207 mm shell length, 0.249-0.255 mm shell height, and 0.105-0.118 mm dorsally along the hinge line. Glochidia from specimens collected in Texas had shells 0.252 x 0.200 mm [RGH].

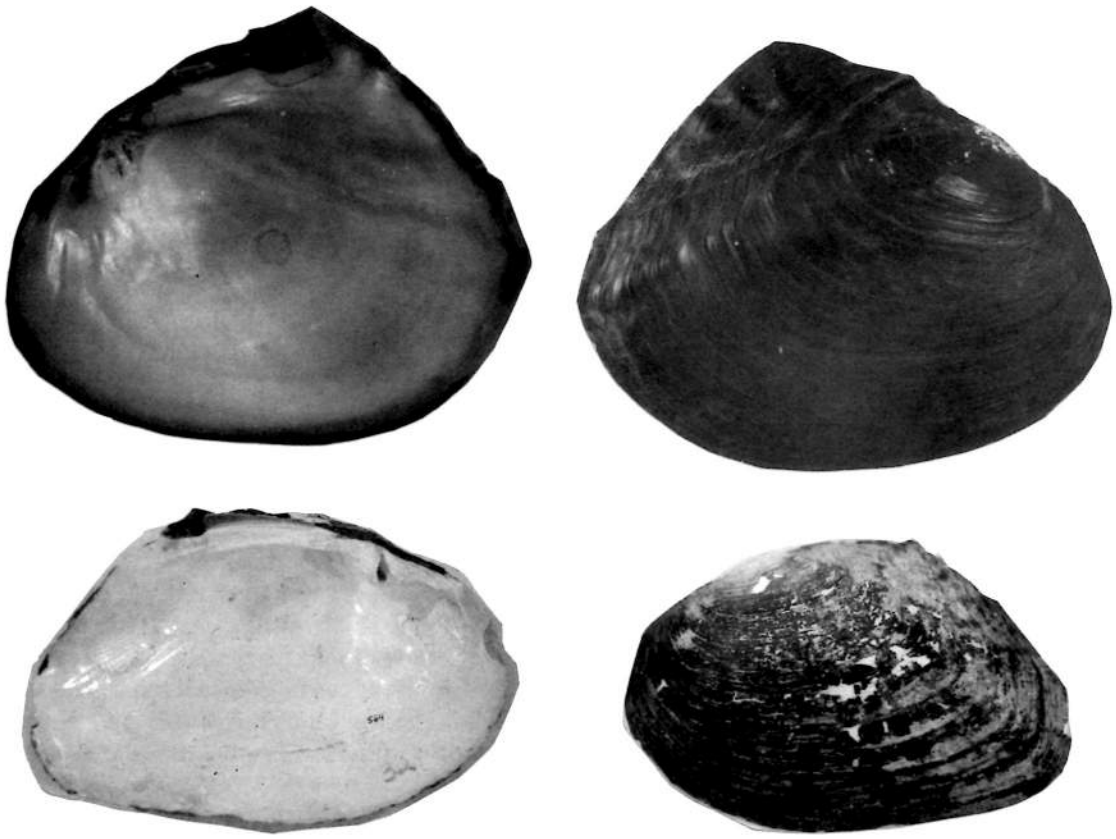
HOSTS: Longnose gar (Lepisosteus osseus) primarily (Oesch 1984); other probable species include shortnose gar (L. platostomus), alligator gar (L. spatula), green sunfish (Lepomis cyanellus), orangespotted sunfish (L. humilis), largemouth bass (Micropterus salmoides), black crappie (Pomoxis nigromaculatus), and white crappie (P. annularis) (Baker 1928), and shovelnose sturgeon (Scaphirhynchus platorynchus) and warmouth (L. gulosus) (Surber 1913).

ECONOMIC IMPORTANCE: Yellow sandshell was once in demand by the shell-button industry because of its extremely pearly nacre; it is less frequently taken at present, with no reports of commercial harvest in Texas in recent years. It is likely taken for mother-of-pearl on occasion.

COMMENTS: The species was described by Coker (1919) as never very abundant, often found on sandy or gravelly shoals, and as having a relatively rapid growth rate such that the species was ready for market in six years (and possibly more rapidly in the south).


YELLOW SANDSHELL
Lampsilis teres
Howells (unpublished)
Metcalf (1982)
Murray (unpublished)
Neck (1987a)
Neck (1989a)
Neck and Metcalf (1988)
Shafer et al. (1992)
Shira (1913)
Strecker (1931)
White and White (1977)

WHITE HEELSPLITTER
Lasmigona complanata



White heelsplitter (Lasmigona complanata): Top Pine Creek, Lamar County, Texas, August 1993; 133 mm shell length; TPWD. Bottom San Marcos River, Gonzales County, Texas, September 1965; 142 mm; TUC.

OTHER COMMON NAMES: Pancake, razorback, elephant-ear, hackleback.

SYNONYMY: (Murray and Leonard 1962; Oesch 1984).

Alasmidonta complanata Barnes 1823
Margaritana complanata Call 1885
Symphynota complanata (Barnes), Simpson 1900
Symphynota complanata, Scammon 1906
Lasmigona complanata, Ortmann 1919

DISTRIBUTION: Reported from Lake Texoma (White and White 1977), the Red River and Lake Lewisville (Neck 1982c) in northern Texas, and Pine Creek in Lamar County [RGH]. A specimen from the San Marcos River in central Texas is present in the Trinity University collection [HDM]; however, this species was not taken in TPWD sampling at the collection site in Gonzales County in 1992 or 1993 where no living unionids appear to remain [RGH].

DESCRIPTION: (Murray and Leonard 1962; Valentine and Stansbery 1971; Oesch 1984).

Size: To 167 mm shell length in Texas [RGH]; also reported to 173 mm in Missouri (Oesch 1984), 178 mm in Kansas (Murray and Leonard 1962), and 216 mm in Illinois (Valentine and Stansbery 1971).

Shell: Large; ovate, more triangular in young and more oblong, rhomboidal, or oval in older individuals; often strongly alate, wing fluted with four to five ridges; strongly compressed; shell thin relative to size, but solid; dorsal line straight but may be eroded, rounded anteriorly and ventrally, posteriorly straight to concave or obliquely truncated (angled where the posterior ridge meets the edge); beaks small and not raised above the hinge line, beak cavities shallow and narrow; posterior ridge well-defined but becoming broad and flat distally; growth-rest periods form concentric ridges and grooves.

Shell Teeth: Two left pseudocardinal teeth, both variable and grooved, anterior tooth low and compressed, posterior tooth more massive; single right pseudocardinal tooth long, triangular, grooved; lateral teeth rudimentary, sometimes only present as low ridges, and non-interlocking.

External Color: Tan in young, brown to black in older specimens; sometimes indistinctly rayed.

Internal Color: White to bluish-white, sometimes tinted with cream; partially or wholly iridescent.

Soft Tissues: Mostly yellowish in color; gills rusty when gravid.

HABITAT: It typically occurs in large rivers and streams with sluggish, turbid waters, on mud or mud-gravel bottoms; it may also occur in smaller streams and reservoirs and is usually found deep in soft mud or occasionally found among rocks; it may be found in quiet areas of otherwise swift streams; and rare in upper reaches of fast-flowing rivers (Buchanan 1980; Murray and Leonard 1962; Oesch 1984). Valentine and Stansbery (1971) indicated greatest abundance in mud and silt. White heelsplitter was reported by Stansbery (1965) as one of the most pollution-tolerant of all naiads.

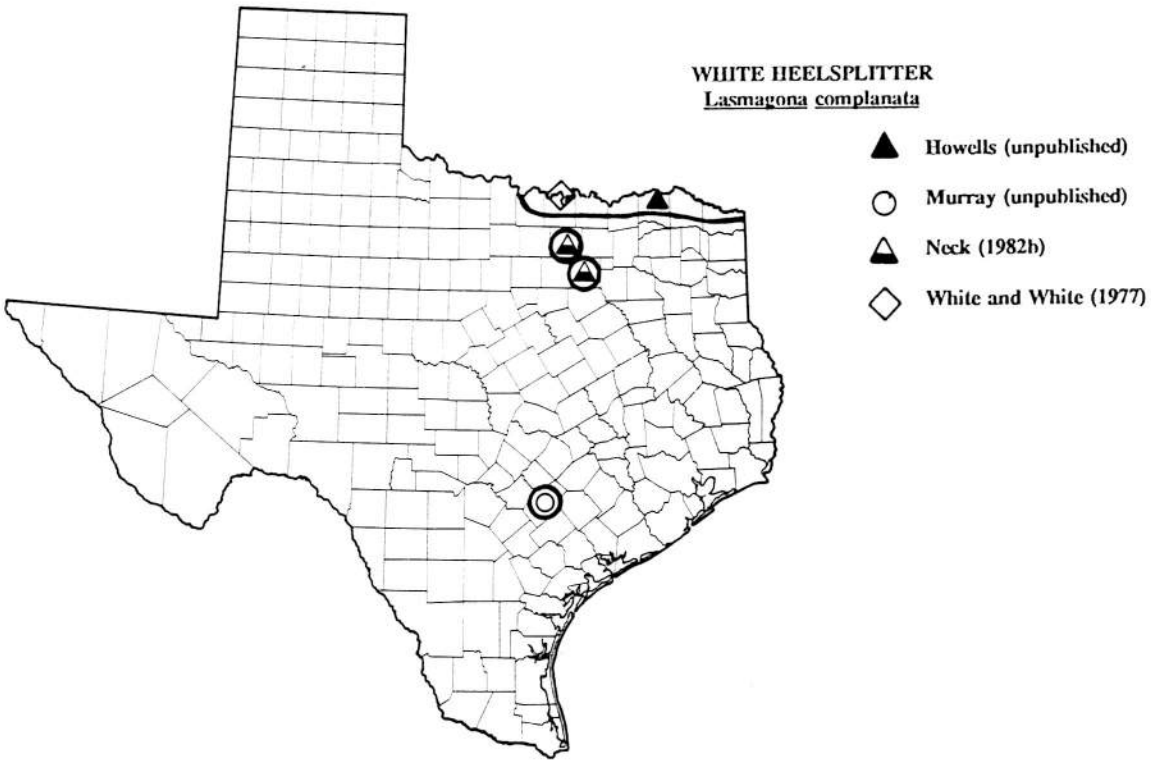
SPAWNING: It is bradytictic, breeding from September to April or May (Baker 1928); Hoggarth (1988) reported glochidia in September and October. Females taken in Lamar County in August were found to contain developing eggs when examined in September after one month in research station tanks [RGH].

GLOCHIDIA: Shell very large, 0.310 x 0.320 mm; spined; hinge line undulate (Surber 1912). Hoggarth (1988) described glochidia as pear-shaped (pyriform), almost symmetrical, 0.289-0.296 mm shell length, 0.293-0.310 mm shell height, and 0.195-0.208 mm dorsally along the hinge line, with styliform hooks with about 100 microstylets in six proximal and four distal rows.

HOSTS: Common carp (Cyprinus carpio), green sunfish (Lepomis cyanellus), largemouth bass (Micropterus salmoides), and white crappie (Pomoxis annularis) (Lefevre and Curtis 1910, 1912; Fuller 1978).

ECONOMIC IMPORTANCE: Typically none. White heelsplitter has been reported to produce pearls (Kunz 1897), but usually not harvested for this reason. It may be of interest for mother-of-pearl chips, but there is no indication of harvest for this purpose locally. Murray and Leonard (1962) indicated large shells were occasionally valued by the button industry in the past.

COMMENTS: White heelsplitters, though often deeply buried, normally assume a position with the wing projecting upward from the substrate (Murray and Leonard 1962).


WHITE HEELSPLITTER
Lasmagona complanata
Howells (unpublished)
Murray (unpublished)
Neck (1982b)
White and White (1977)

FRAGILE PAPERSHELL
Leptodea fragilis

Fragile Papershell (Leptodea fragilis): Top right Neches River, Jasper County, Texas, May 1993; 46 mm shell length; TPWD. All others Concho River, Concho County, Texas, June 1993; top left 90 mm; bottom left 115 mm, center 115 mm; bottom right 117 mm; TPWD.

OTHER COMMON NAMES: Paper heelsplitter, paper shell, cottonmouth.

SYNONYMY: (Murray and Leonard 1962; Oesch 1984).

Unio fragilis Rafinesque 1820
Unio gracilis Barnes 1823
Lasmonos fragilis Rafinesque 1831
Unio dolosus Lea 1861
Lampsilis gracilis, Simpson 1900
Paraptera gracilis, Ortmann 1912
Leptodea gracilis, Simpson 1914
Lampsilis gracilis (Barnes) = U. fragilis (Raf.) = Lasmonos fragilis (Raf.), Walker 1918
Leptodea fragilis, Ortmann and Walker 1922

DISTRIBUTION: Occurs from the Colorado River basin into drainages to the north and east.

DESCRIPTION: (Murray and Leonard 1962; Valentine and Stansbery 1971; Oesch 1984; Fuller 1985; RGH).

Size: To 133 mm shell length in Texas (Neck 1989a); also reported to 160 mm in Missouri (Oesch 1984), 152 mm in Kansas (Murray and Leonard 1962), and 178 mm in Illinois (Haas 1941).

Shell: Oblong, elliptical, or ovate; females expanded posteriorly; males often greatest in height near the middle of the valve, females posterior to the middle; thin, brittle, fragile, often cracks upon drying; large right-

angled wings may be present or absent (eroded or broken) posteriorly, and a smaller anterior wing may also be present; dorsal margin may be rounded if wing is completely eroded away to strongly angular with wing present; rounded anteriorly and posteriorly (more bluntly truncated in females), ventrally straight or slightly rounded; compressed side to side; beaks low, beak cavities shallow; posterior ridge rounded and ill-defined; shell relatively smooth, with fine concentric growth lines.

Shell Teeth: Two left pseudocardinal teeth low thin, parallel to dorsal line, but posterior tooth may be absent; single right pseudocardinal tooth low, thin; left lateral teeth short, low, thin, slightly curved; right lateral tooth smooth, slightly curved, sometimes high.

External Color: Light yellowish-tan or yellow-green in young, to brown in older specimens; green rays may cover the entire shell or be completely absent.

Internal Color: Bluish-white to silvery-white; sometimes slightly pink-tinted dorsally; purple coloration may be most intense at muscle scars; often iridescent; nacre relatively thin and transparent in very young shells.

Soft Tissues: Whitish in color, gills dark tan but in gravid females become enlarged, gelatinous, and semitransparent (rather than milky-white as in other unionids); foot is very large and extensile.

HABITAT: It may occur in small streams to large rivers; on mud, mud and gravel, gravel, and occasionally on pure sand; and in clear or murky waters (Oesch 1984); it may occur on silt (Buchanan 1980), or rocky bottoms, in deep or shallow waters (Murray and Leonard 1962); in still to swiftly flowing waters (57.9 cm/second) (Buchanan 1980). The species has been reported as tolerant of environmental alteration, and as possibly exploiting impoundments (Fuller 1985).

SPAWNING: The species is bradytictic, breeding August to mid-July (Ortmann, cited in Oesch 1984). Glochidia have been reported present April (Hoggarth 1988), and July and August (Baker 1928); Littleton (1979) reported gravid females in the Navasota River, Texas, in March, with a minimum shell length at maturity of 53 mm; females with glochidia were taken in central Texas June-September [RGH].

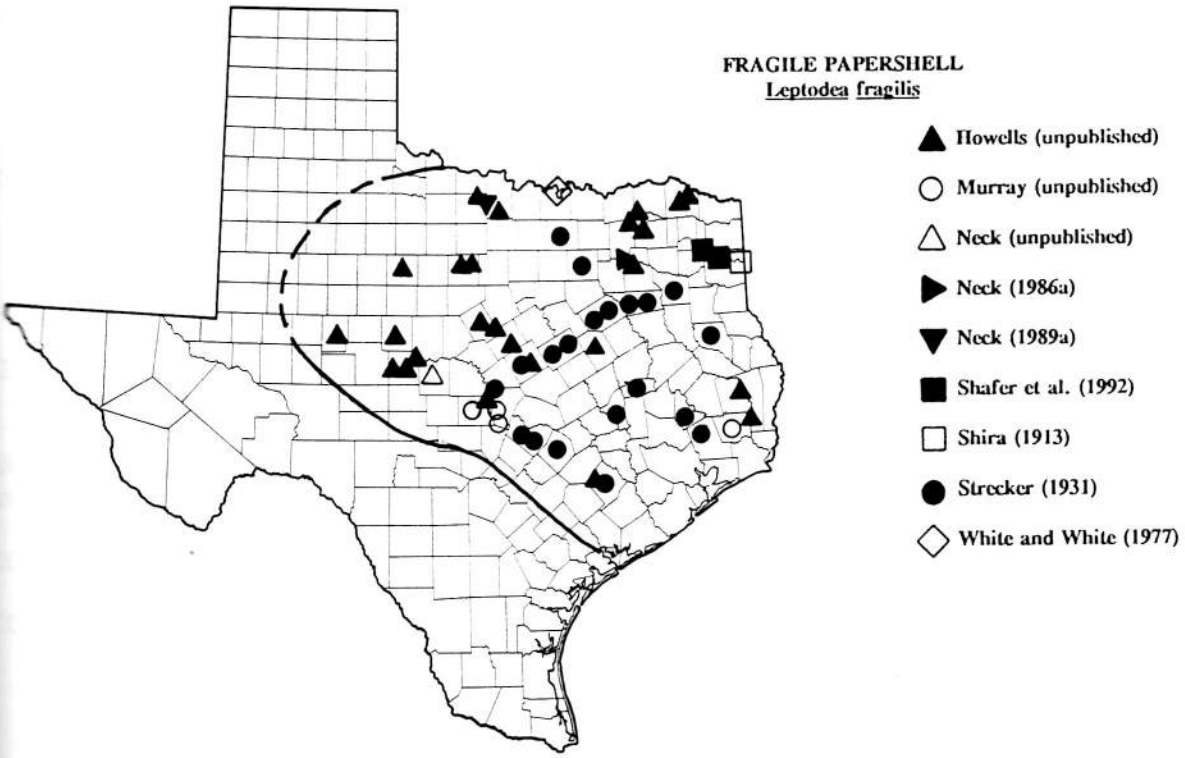
GLOCHIDIA: Shells very small, 0.085 x 0.075 mm, subelliptical, ventral margin rounded, gaping hookless, short hinge line undulate (Utterback 1915-16). Hoggarth (1988) described glochidia as subelliptical, very small, 0.072-0.073 mm shell length, 0.080-0.083 mm shell height, and 0.030-0.035 mm dorsally along the hinge line.

HOSTS: Freshwater drum (Aplodinotus grunniens) (Fuller 1978).

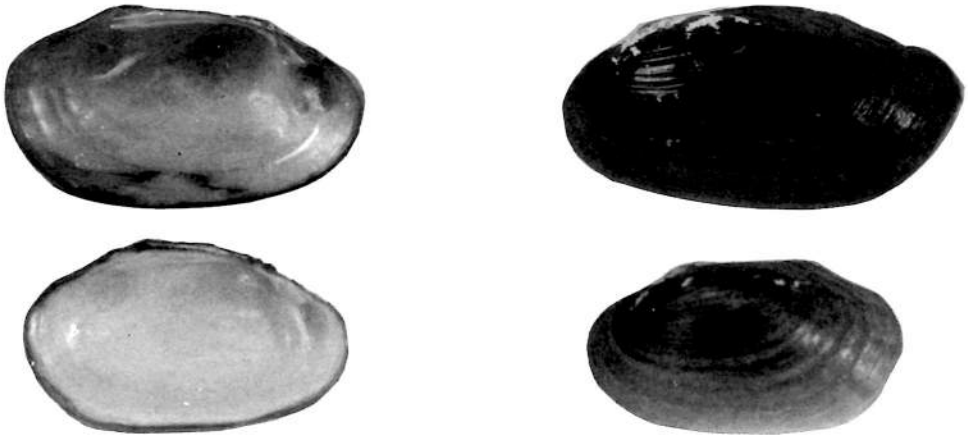
ECONOMIC IMPORTANCE: None.

COMMENTS: Fragile papershell may be confused with pink papershell Potamilus ohiensis which is often more boldly purple interiorly, sometimes nearly black exteriorly, and may have hinge teeth which are slightly larger and more clearly defined.

Ortmann (1919) described fragile papershell as an active species, often crawling with unusual speed. Strecker (1931) indicated the species would die if water depth dropped below 15.2 cm; however, specimens have been maintained at TPWD's Heart of the Hills Research Station for many months in flow-through raceways at water depths less than 15 cm.


FRAGILE PAPERSHELL
Leptodea fragilis
Howells (unpublished)
Murray (unpublished)
Neck (unpublished)
Neck (1986a)
Neck (1989a)
Shafer et al. (1992)
Shira (1913)
Strecker (1931)
White and White (1977)

POND MUSSEL
Ligumia subrostrata



Pond mussel (Ligumia subrostrata): Giddings State School Lake, Lee County, Texas, June 1993; bottom 68 mm shell length, top 69 mm; TPWD.

OTHER COMMON NAMES: Western pondmussel, western sandshell, common pondmussel.

SYNONYMY: (Murray and Leonard 1962; Murray and Roy 1968; Oesch 1984).

Unio subrostratus Say 1831
Unio mississippiensis Conrad 1850
Unio topekensis Lea 1868
Unio rutersvillensis Lea 1859
Lampsilis subrostratus, Simpson 1900
Erynia subrostrata (Say), Ortmann 1912
Ligumia subrostrata, Grier and Mueller 1922

DISTRIBUTION: Nueces and Guadalupe rivers into drainages to the north and east.

DESCRIPTION: (Murray and Leonard 1962; Oesch 1984).

Size: To 74 mm shell length in Texas [RGH], and larger [RWN]; reported to 97 mm in Missouri (Oesch 1984), and 83 mm in Kansas (Murray and Leonard 1962).

Shell: Somewhat elongate to nearly elliptical; slightly inflated, more so in females; not especially thick; occasionally weakly winged; dorsal margin slightly curved, ventral margin straight or slightly curved, rounded anteriorly, posteriorly centrally pointed in males and blunt in females with a dorso-posterior point (not ventro-posterior); beaks broad and low, only slightly raised above hinge line, beak cavities moderate; externally growth rings may or may not form irregular ridges.

Shell Teeth: Left valve with two pseudocardinal teeth thin, erect, emarginate, rough, and nearly parallel to hinge line; right valve with a single pseudocardinal tooth thin, erect, and emarginate, with a low, thin tooth (or denticle) placed anteriorly; lateral teeth long, thin, slightly curved.

External Color: Light brown, yellowish-brown, or greenish-brown, becoming black with age; often with greenish rays which may become obscure in older specimens; locally some individuals show reddish highlights, especially around the beak and upper shell.

Internal Color: Generally grayish-white to white, slightly pearly posteriorly.

Soft Tissues: Mantle near siphons black; ovisacs bluish when containing glochidia. Females may display numerous, elongate, papillae-like extensions of the mantle posteriorly (black) and posterio-ventrally (white) with other shorter papillae on the excurrent siphon [RGH].

HABITAT: Pond mussel adapts well to small, shallow ponds, oxbows, sloughs, and streams, on hard to soft mud, or rarely on rock (Murray and Leonard 1962). It has also been reported from silt, gravel and cobble, and cobble; at depths of 5.1-106.7 cm; and from still to swiftly flowing waters (57.9 cm/second) (Buchanan 1980).

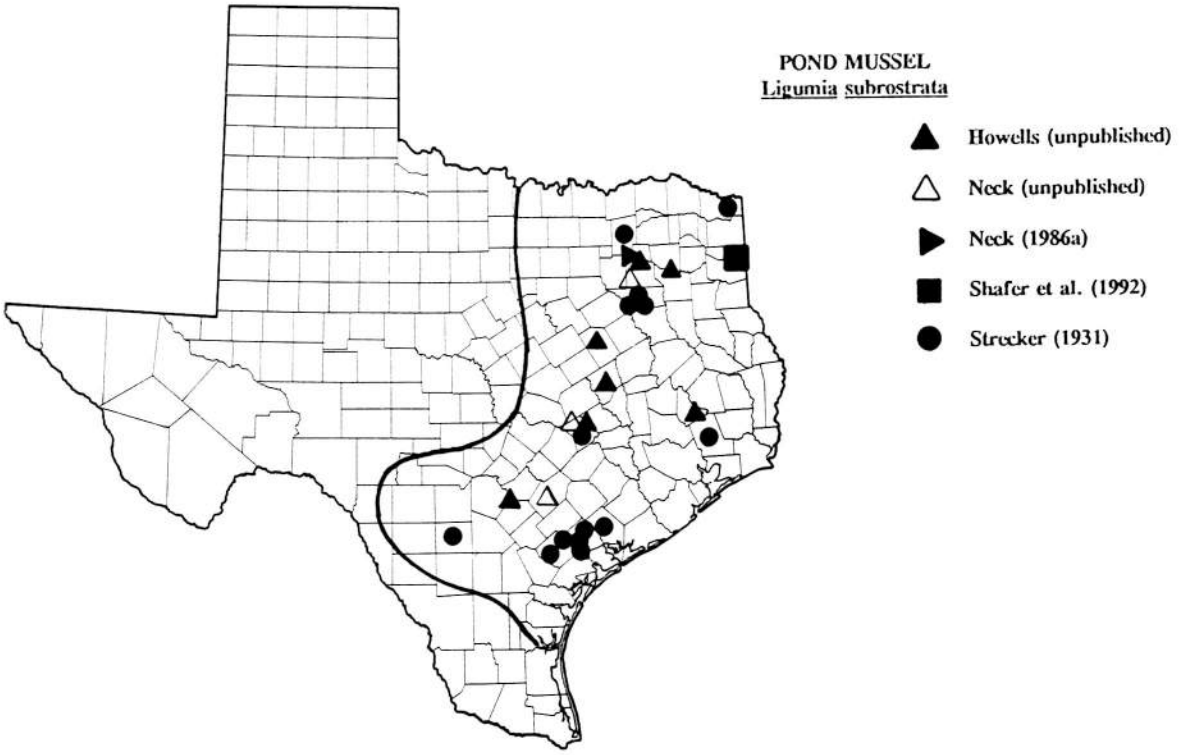
SPAWNING: Oesch (1984) listed pond mussel as probably bradytictic. Utterback (1915-16) indicated spawning season was long. Littleton's (1979) report of little spectaclecase (Villosa lienosa) in the Navasota River is referable to pond mussel [RWN]; Littleton found gravid females in July and August with a minimum shell length of 43 mm. A female with glochidia in outer gill marsupia only was taken in Lee County, Texas, in early June [RGH].

GLOCHIDIA: Large semi-elliptical, spineless, regularly rounded ventrally, hinge line straight, 0.270 x 0.330 mm (Utterback 1915-16).

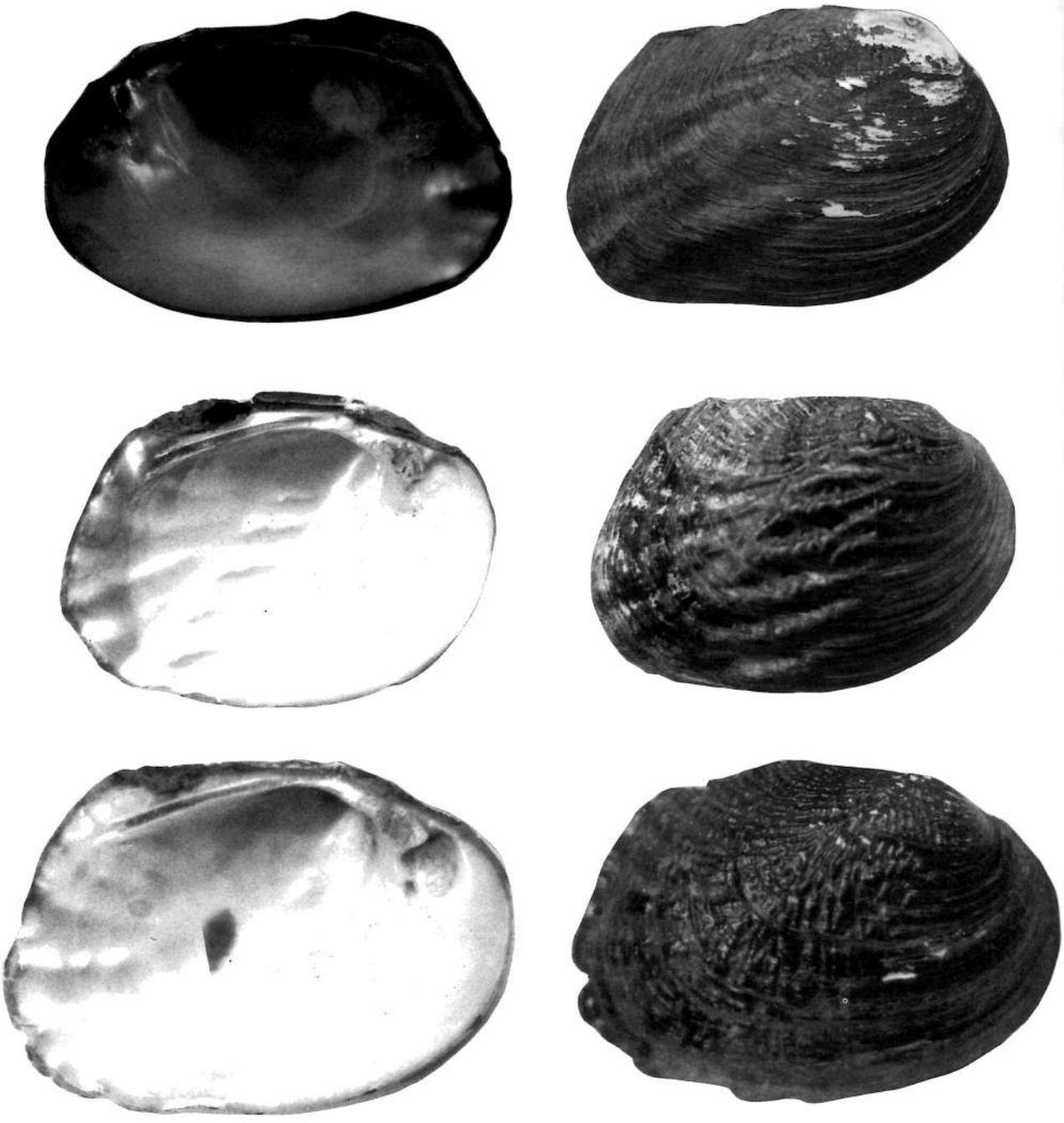
HOSTS: Green sunfish (Lepomis cyanellus), orangespotted sunfish (L. humilis), bluegill (L. macrochirus), and largemouth bass (Micropterus salmoides) (Fuller 1978).

ECONOMIC IMPORTANCE: None.

COMMENTS: Pond mussel, along with pondhorns (Uniomerus spp.) and paper pondshell (Anodonta imbecillis), is sometimes found in small, shallow water bodies where other mussels may not occur. Pond mussel is sometimes confused with pondhorns, larger lilliputs (Toxolasma spp.), and some Lampsilis spp., but differs in having numerous v-shaped ridges on the beaks with the open ends spread wide apart (Murray and Leonard 1962). Additionally, pondhorns are generally more pointed posterio-ventrally; pond mussels are pointed posterio-centrally in males and posterio-dorsally in females [RGH].



WASHBOARD
Megalonaias nervosa



Washboard (Megalonaias nervosa): Top and bottom Little Brazos River, Robertson County, Texas, August 1992; top 190 mm shell length; bottom 78 mm; TPWD. Center Lake Wood, Gonzales County, Texas, July 1992; 131 mm; TPWD.

OTHER COMMON NAMES: Giant washboard, lake board, river board, bald-pate.

SYNONYMY: (Strecker 1931; Murray and Leonard 1962; Murray and Roy 1968; Oesch 1984).

Unio nervosa Rafinesque 1820
Unio giganteus Barnes 1823
Unio undulatus Barnes 1823
Unio heros Say 1829
Unio multiplicatus Lea 1831
Unio eightsi (also eightsii) Lea 1860
Quadrula heros, Simpson 1900
Crenodonta heros (Say), Ortmann 1912
Amblema gigantea (Barnes 1923), Strecker 1931 and Starrett 1971
Megalonaias Utterback 1915
Megalonaias heros (Say), Utterback 1916
Megalonaias gigantea, Ortmann and Walker 1922
Megalonaias nervosa (Rafinesque 1820)

Murray and Leonard (1962) indicated some old records of U. multiplicatus in Kansas collectively included both washboard and threeridge (Amblema plicata).

DISTRIBUTION: All major river systems.

DESCRIPTION: (Murray and Leonard 1962; Valentine and Stansbery 1971; Oesch 1984; RGH).

Size: Specimens in Texas commonly 200-230 mm shell length, reports from local musselers of individuals 300-431 mm are unconfirmed [RGH]; also reported to 180 mm in Missouri (Oesch 1984), 210 mm in Kansas (Murray and Leonard 1962), and 280 mm in Kentucky, apparently the largest formally on record (Haas 1941).

Shell: Very large and often massive, the largest North American unionid; quadrate to rhomboidal, occasionally nearly oval; solid; thick in larger specimens, but sometimes surprisingly thin in smaller animals; dorsally nearly straight, anteriorly rounded, posteriorly rounded to slightly rounded, ventrally gently rounded to nearly straight; beaks narrow, not raised above hinge line, beak cavities deep; externally has deeply-sculptured wavy ridges which may extend to the posterior and ventral margins, and often into the anterior field in front of the beak.

Shell Teeth: Two left pseudocardinal teeth, rough, grooved, divergent, triangular; one right pseudocardinal tooth similar to left, with a small anterior denticle; lateral teeth long and nearly straight.

External Color: Light brown to black, darker with age; rayless. Some medium-sized individuals from the middle Guadalupe River are tan with black and white marbling [RGH].

Internal Color: White, iridescent posteriorly, rarely tinted with pink or purple. Metallic gold markings and spots are frequently present; such markings may be related to infection (Oesch 1984).

Soft Tissues: Usually fleshy-tan or off-white; gravid marsupia form purplish-black pads, sometimes with rusty-brown placentae.

Habitat: Washboards typically occur in large, low-velocity, deep rivers on mud or gravel (Coker et al. 1921; Oesch 1984). Neck (1982b) indicated washboards require 6.1-22.4 m depths, and Murray and Leonard (1962) did not collect the species at depths less than 1.8 m. However, several individuals were taken in Lake Wood and Lake Gonzales, Gonzales County, Texas, at 0.9-1.2 m, and the species was found abundant in the Little Brazos River, Robertson County, Texas, at 0.3-0.9 m in depth, though such occurrences are atypical. Though typically a large-river species, washboards can adapt to conditions in some reservoirs. Buchanan (1980) reported the species from silt, gravel, cobble, or mixed cobble and boulders in standing to moderately fast (45.7 cm/second) waters. Williams and Schuster (1989) found washboards in the Ohio River at depths greater than 18 m.

SPAWNING: Harris and Gordon (undated) indicated spawning behavior was unclear with the species being reported as both a bradytictic, long-term and tachytictic, short-term breeder. Typically, embryos appear in early fall, are carried through the winter, and released by April (Utterback 1915-16). However, spawning may also occur in two periods September-February and April-May. This possible double spawning period was not observed among washboards examined by TPWD in 1992 and 1993 [RGH]. Musselers reported gravid washboards in mid- to late September in central Texas, specimens from the Little Brazos River (Robertson County) carried glochidia into late November, and in TPWD research stations ponds (Kerr County) glochidia were only partially spent by late December and early January. Littleton (1979) collected gravid females in the Navasota River, Texas, and reported the smallest gravid female was 156 mm in length. Some states close musseling seasons during late fall and winter to protect washboards during the breeding season.

GLOCHIDIA: Shell large, 0.280 x 0.340 mm, obliquely rounded, broad posterio-ventrally, hinge line nearly straight, spineless, described as "very vital" (Utterback 1915-16). Hoggarth (1988) described glochidia as subelliptical, 0.254-0.268 mm long, 0.340-0.350 mm in height, and 0.145-0.155 mm dorsally along the hinge line.

HOSTS: Bowfin (Amia calva), gizzard shad (Dorosoma cepedianum), skipjack herring (Alosa chrysochloris), American eel (Anguilla rostrata), highfin carpsucker (Carpiodes velifer), black bullhead (Ameiurus melas), brown bullhead (A. nebulosus), channel catfish (Ictalurus punctatus), flathead catfish (Pylodictis olivaris), tadpole madtom (Noturus gyrinus), white bass (Morone chrysops), bluegill (Lepomis macrochirus), largemouth bass (Micropterus salmoides), white crappie (Pomoxis annularis), black crappie (P. nigromaculatus), sauger (Stizostedion canadense), and freshwater drum (Aplodinotus grunniens) (Baker 1928; Fuller 1978; Hoggarth 1992).

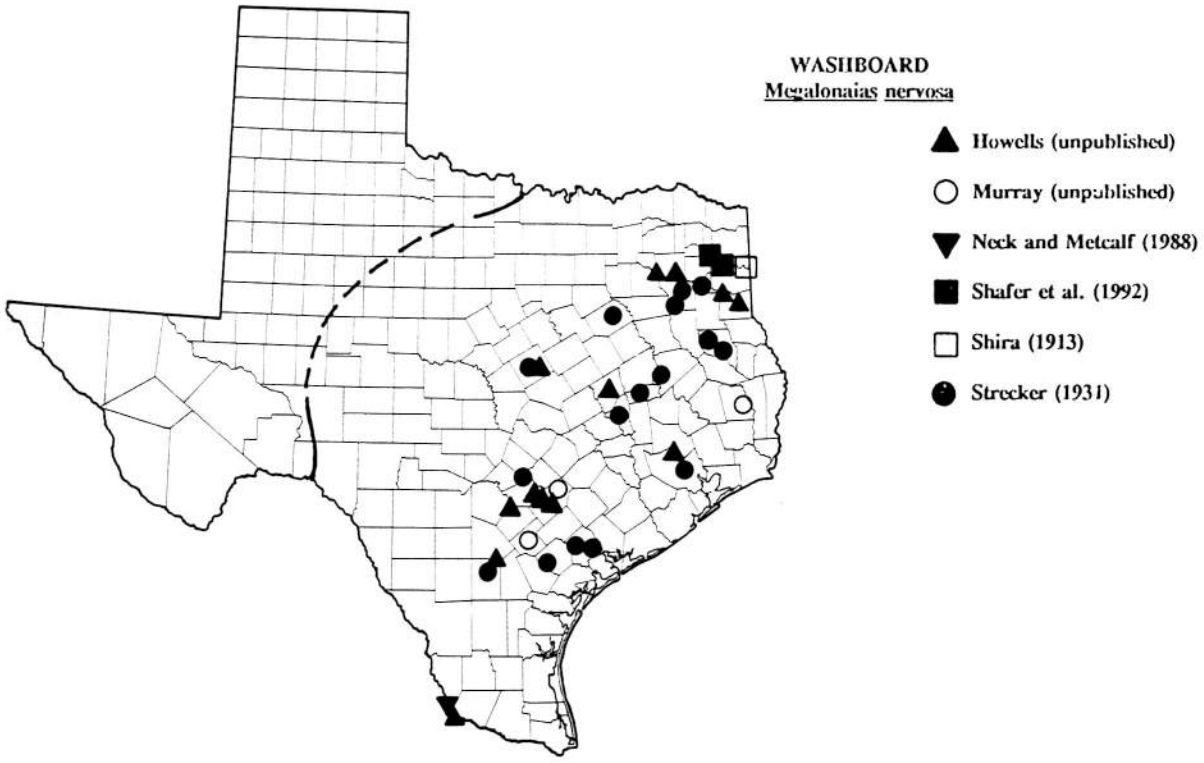
ECONOMIC IMPORTANCE: This species was previously important in the button industry of the Mississippi Valley (Coker et al. 1921). In recent years, washboards became one of the primary species for shell used in the cultured pearl industry, and during certain periods were often the only species purchased by some shell buyers. Washboards are also used as pearl culture mussels in Tennessee, though Texas efforts appear to center on Tampico pearlymussel (Cyrtonaias tampicoensis).

COMMENTS: Washboards are sometimes confused with threeridges, but differences include: (1) beak sculpturing often extends into the anterior field in washboards but never does in threeridges, (2) washboards attain a much larger maximum size than do threeridges, (3) among equal-sized specimens (i.e., smaller washboards and larger threeridges), washboards are usually much thinner-shelled than threeridges, (4) among equal-sized specimens, washboards are usually rather compressed from side to side, threeridges are often comparatively more inflated (washboards may show inflated valves in larger specimens, but almost never do in juveniles).

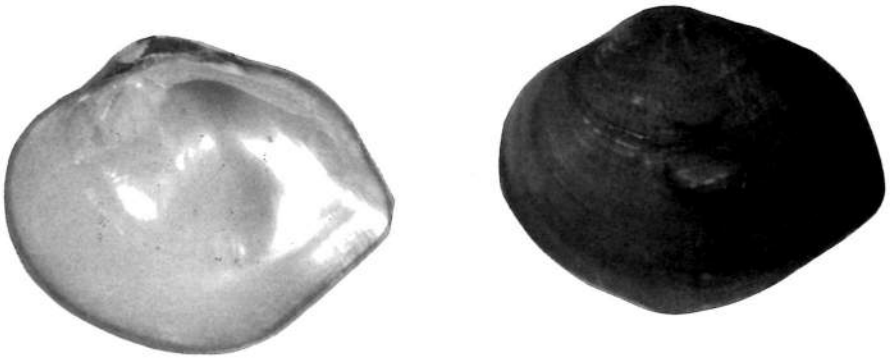
Washboards may also be confused with rock-pocketbooks (Arcidens confragosus) which are (1) never as large, (2) thinner shelled, (3) inflated at small sizes at which washboards would be compressed, (4) more irregularly sculptured, (5) often have beaks which are more nearly centered than in washboards where beaks may be placed more posteriorly, and (6) have lateral teeth lacking or reduced to slight ridges, not the massive and well-developed lateral teeth present in washboards.

Although most washboard populations in Texas seem to have escaped the massive harvest that depopulated many in the Mississippi Valley, local populations have come under very heavy harvest pressure in the last few years. One resident on one of the Guadalupe River reservoirs reported a bed of washboards several hundred meters long that persisted adjacent to his home for many years. However, the bed was located by an out-of-state shell survey crew, and the following week some 55 musselers arrived with boats, diving equipment, and drag buckets. When TPWD surveyed the site in 1992, no washboards could be found at that location, and only a single specimen was taken in the same reservoir during two surveys that year. In the absence of previous population surveys and standing crop estimates, it is difficult to assess the extent and impact of such heavy washboard harvest. Among over 50 locations examined by TPWD in preliminary 1992 mussel surveys, live washboards were present at only four locations, and abundant at only one. It is

entirely possible that many populations in Texas will be, or have been, lost before scientifically studied and documented.



THREEHORN WARTYBACK
Obliquaria reflexa



Threehorn wartyback (Obliquaria reflexa): Pine Creek, Lamar County, Texas, August 1993; 44 mm shell length; TPWD.

OTHER COMMON NAMES: Threeknot, threehorn, threedot, hornyback.

SYNONYMY: (Murray and Leonard 1962; Oesch 1984).
Obliquaria reflexa Rafinesque 1820
Unio cornutus Barnes 1823
Obliquaria reflexa (Rafinesque), Simpson 1900
Obliquaria reflexa Rafinesque, Murray and Leonard 1962

DISTRIBUTION: Occurs from the Trinity River drainage basin into systems to the north and east.

DESCRIPTION: (Clench 1959; Murray and Leonard 1962; Valentine and Stansbery 1971; Oesch 1984; Fuller 1985).

Size: To at least 46 mm shell length in Texas [RGH]; also reported to 80 mm in Missouri (Oesch 1984), 76 mm in Kansas (Murray and Leonard 1962), and to 84 x 72 mm in Ohio (Valentine and Stansbery 1971).

Shell: Small, stout, inflated, irregular outline; shell thicker anteriorly and thinner posteriorly; dorsal margin short and straight, rounded anteriorly and ventrally, convexly pointed posteriorly; shallow sulcus present anterior to the posterior ridge; beaks narrow and raised above hinge line, beak cavities deep; posterior slope with well-defined corrugations; 2-5 (usually 3) large knots externally on the valves which are positioned alternately from those on the opposite shell.

Shell Teeth: Two left pseudocardinal teeth, heavy, large, rough, and deeply grooved; single right pseudocardinal tooth large, grooved, with a small anterior lamellar denticle; lateral teeth short and nearly straight.

External Color: Light tan, yellow, green, reddish-brown, or brown, becoming darker with age; shell may be covered with fine or variable-width green or brown rays or with evenly radiating rows of small, dark spots; shiny.

Internal Color: White, occasionally pink or purple; iridescent posteriorly.

Soft Tissues: Gray or dirty white; gills tan or white in non-reproductive specimens.

HABITAT: This species occurs in medium to large rivers, often in gravel, sand and gravel, or mud and gravel, in areas with moderate current (Murray and Leonard 1962). It may also occur in small rivers, on silt and

cobble, at depths of 2.5 cm to 1.2 m in standing water (Buchanan 1980) and has been reported to tolerate impoundment and unstable bottoms (Fuller 1985). It is frequently found with other mussels (Coker 1919).

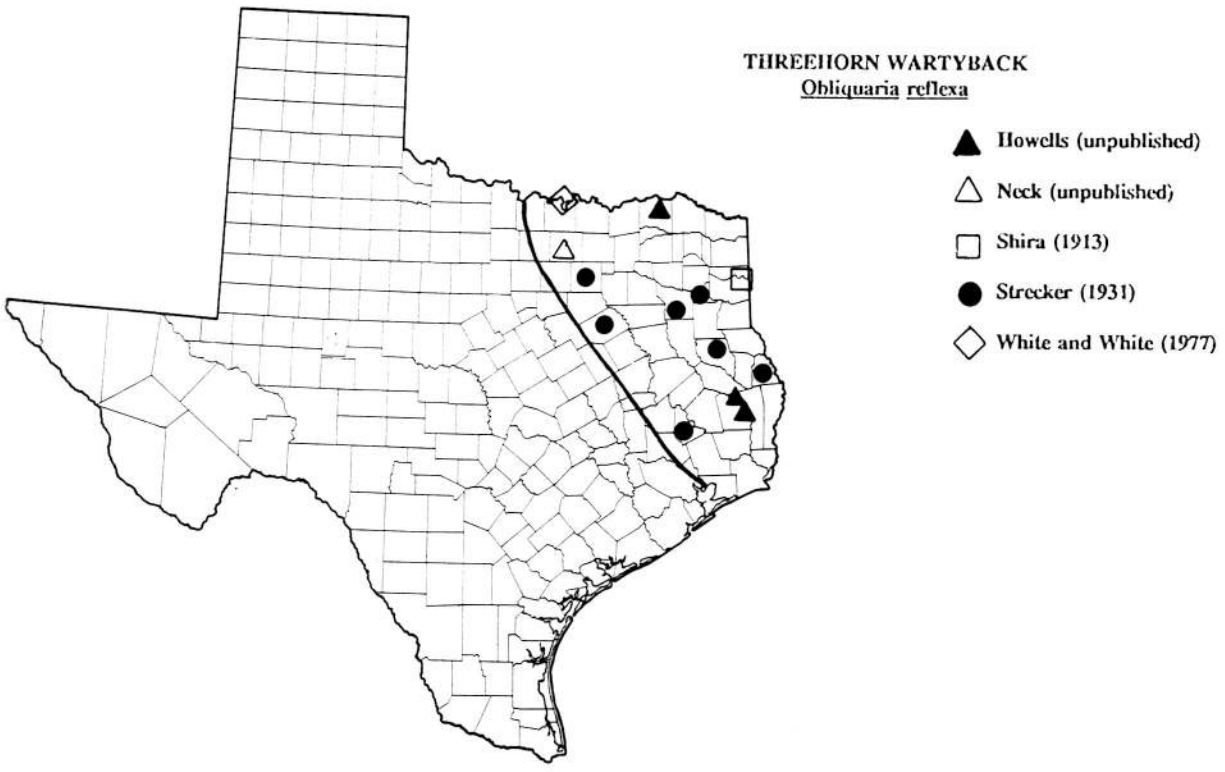
SPAWNING: Threehorn wartyback has been listed as a short-term tachytictic breeder with females gravid in June, July, and August (Utterback 1915-16), and also as a long-term bradytictic breeder (Buchanan 1980). Hoggarth (1988) reported glochidia in October. Reproduction in Texas is undescribed; specimens taken in the Neches River, Jasper County, in early May were not gravid [RGH]. Reportedly females discharge glochidia in conglutinate masses, but glochidia may not leave these masses after they are extruded by the female (Oesch 1984). Attempts at inducing infection in possible host fish in the laboratory have been unsuccessful, thus suggesting metamorphosis may be possible without a host (Oesch 1984).

GLOCHIDIA: Shell medium-sized, 0.225 x 0.235 mm, semicircular, hinge line slightly upcurved at center (Utterback 1915-16). Hoggarth (1988) described glochidia as rotund, symmetrical, 0.213-0.219 mm shell length, 0.206-0.221 mm in shell height, and 0.140-0.147 mm dorsally along the hinge line.

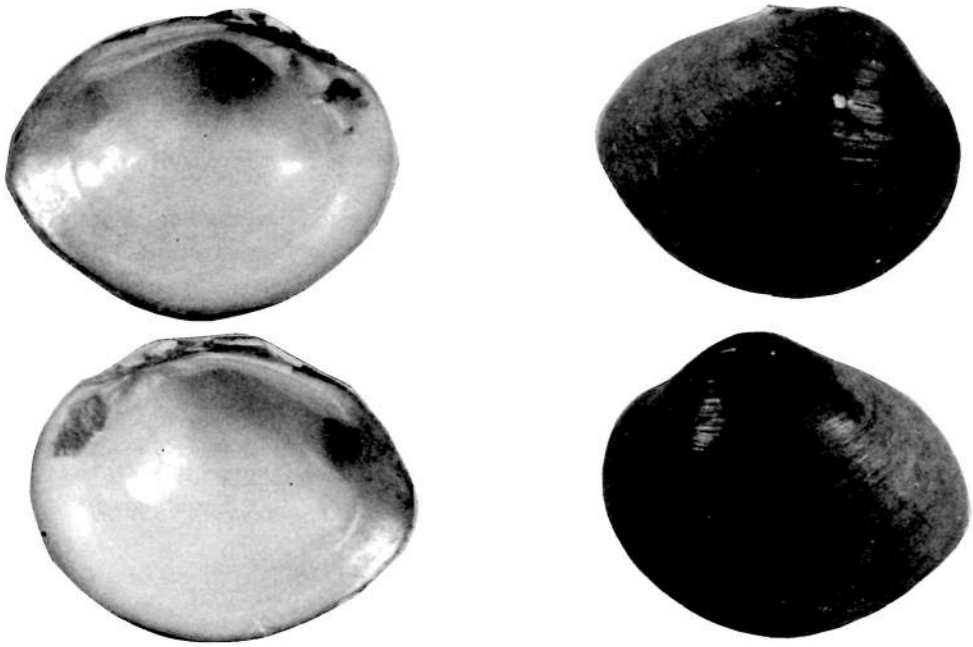
HOSTS: None reported (Howard 1914a; Oesch 1984).

ECONOMIC IMPORTANCE: None.

COMMENTS: Threehorn wartyback could be confused with pimpleback (Quadrula pustulosa) or other quadrulids in Texas; however, none have alternating nodules. Indeed, no other Texas naiad has alternating knobs.



SOUTHERN HICKORYNUT
Obovaria jacksoniana



Southern hickorynut (Obovaria jacksoniana): Village Creek, Hardin County, Texas, August 1980; 37 mm shell length; HMNS.

OTHER COMMON NAMES: Hickorynut.

SYNONYMY: (Strecker 1931; Murray and Roy 1968; Oesch 1984; Vidrine 1993).

Obovaria castaneus Lea 1830 (also 1831)
Unio castaneus Lea 1831
Obovaria castanea Lea 1831
Unio jacksonianus Frierson 1912
Obovaria jacksoniana (Frierson 1912)

DISTRIBUTION: Occurs in the Neches, Sabine, and Red river drainages of eastern Texas.

DESCRIPTION: (Burch 1973; Oesch 1984).

Size: Reported to 43 mm shell length in Missouri (Oesch 1984).

Shell: Small, elliptical, clearly longer than high; stout; moderately inflated; dorsal and ventral margins gently rounded, rounded anteriorly, posteriorly sharply rounded in males and bluntly truncated in females; beaks broad and low, but raised above hinge line, beak cavities shallow; may show shell erosion associated with vigorous environmental conditions.

Shell Teeth: Two left pseudocardinal teeth stout, erect, rough, triangular; one right pseudocardinal tooth erect, columnar, emarginate, and with an additional small compressed denticle (or tooth) anteriorly.

External Color: Light to dark brown; often with fine green rays posteriorly.

Internal Color: Bluish-white, iridescent posteriorly.

Soft Tissues: Unreported.

HABITAT: It has been reported in creeks and rivers with moderate current, often found in gravel (Oesch 1984).

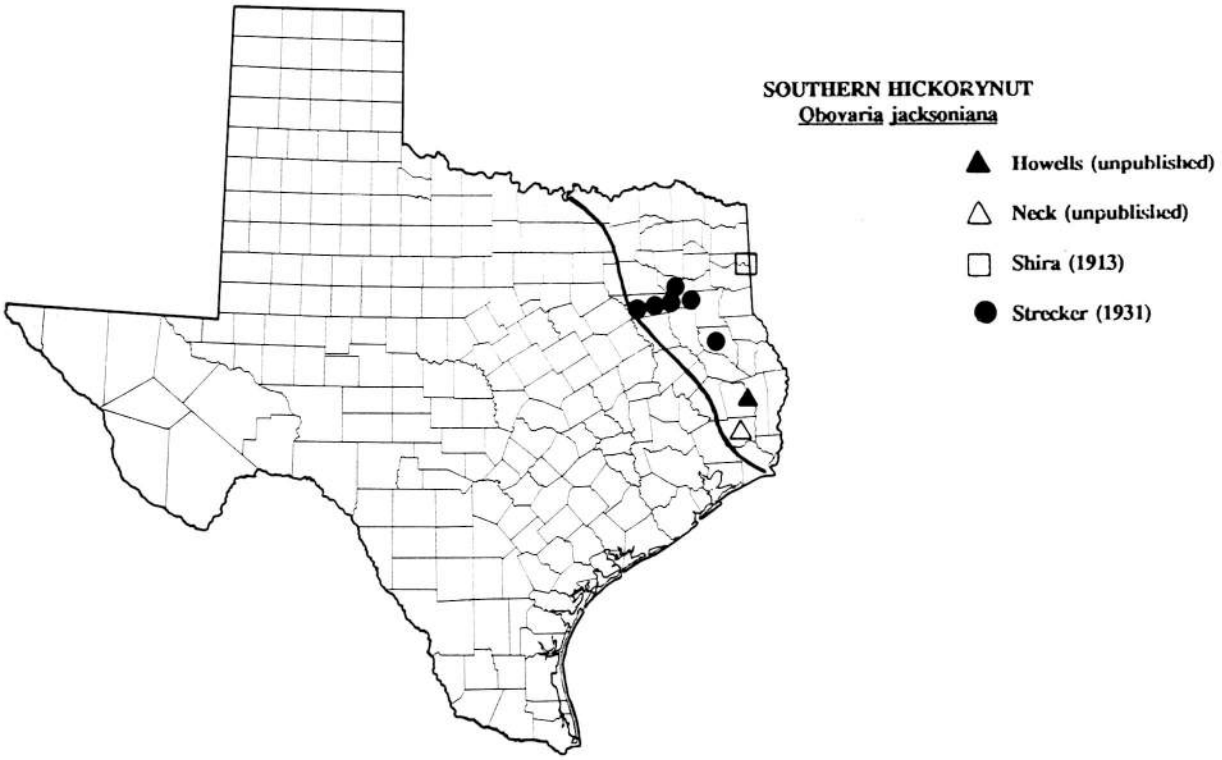
SPAWNING: Hoggarth (1988) reported glochidia in October in Alabama.

GLOCHIDIA: Shell subelliptical, almost symmetrical, 0.175-0.187 mm shell length, 0.230-0.243 mm shell height, 0.089-0.100 mm dorsally along the hinge line, with a dorsal ala about 0.034 mm long, loose-looped sculpturing on the valves, and lanceolate micropoints on the valve margin and flange (Hoggarth 1988).

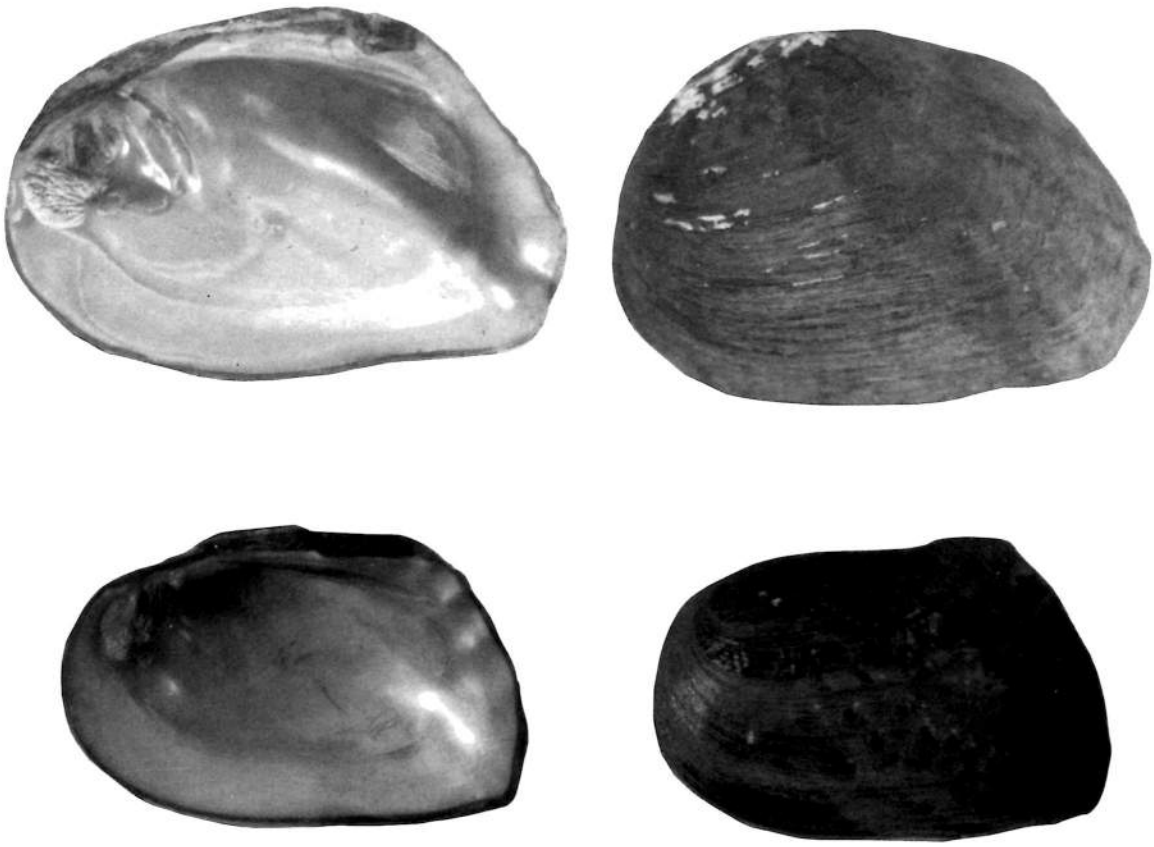
HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

COMMENTS: Southern hickorynut is similar to hickorynut O. olivaria (not found in Texas) which is nearly as high as it is long, and which subsequently has a more centrally-located beak. The American Fisheries Society considers southern hickorynut of special concern (Williams et al. 1993).



BANKCLIMBER
Plectomerus dombeyanus



Bankclimber (Plectomerus dombeyanus): Top Sabine River, Upshur County, Texas, March 1992; 131 mm shell length; TPWD. Bottom B.A. Steinhagen Reservoir, Tyler County, Texas, May 1993; 81 mm; TPWD.

OTHER COMMON NAMES: White-eye, ridge-runner, mudskipper, washboard.

SYNONYMY: (Strecker 1931; Oesch 1984).

Unio crassidens Lamarck 1819
Unio dombeyana Valenciennes 1827
Unio trapezoides Lea 1831
Unio interruptus Say 1831
Unio ponderosus Rafinesque 1831
Unio atromarginatus Lea 1840
Unio sloatianus Lea 1840
Plectomerus Lamarck 1853
Plectomerus crassidens (Lamarck) = Unio interruptus Say = Unio trapezoides Lea, Conrad 1853
Amblema dombeyana Valenciennes, Strecker 1931

DISTRIBUTION: Occurs from the San Jacinto River into drainages to the north and east.

DESCRIPTION: (Burch 1973; Oesch 1984).

Size: To 132 mm shell length in Texas [RGH]; also reported as 142 mm in Missouri (Oesch 1984).

Shell: Large and distinctive; quadrate; stout, not exceptionally thick in smaller specimens, but thick in larger individuals; moderately inflated to relatively compressed; dorsal margin straight, ventral margin straight or nearly so to where the posterior ridge reaches the shell edge, rounded anteriorly, obliquely truncated posteriorly; posterior ridge high and well developed; beaks low and only slightly raised above hinge line, beak cavities shallow; appears rough externally due to concentric growth rings. Described by Strecker (1931) as extremely variable.

Shell Teeth: Two left pseudocardinal teeth, large, divergent, rough, emarginate; right valve with one large pseudocardinal tooth, grooved and triangular, and with small teeth both anteriorly and posteriorly that may appear as slightly raised ridges; lateral teeth long, high, and slightly curved.

External Color: Dark brown, gray-brown, or black.

Internal Color: Deep purple (Coker 1919), paler in small specimens, sometimes tinged with bronze centrally and iridescent posteriorly.

Soft Tissues: White to light tan.

HABITAT: Bankclimber often occurs in ditches and lowland rivers; on mud, mud and gravel, or mud and rock; in moderate to sluggish currents; often near stream banks in shallow waters (Oesch 1984).

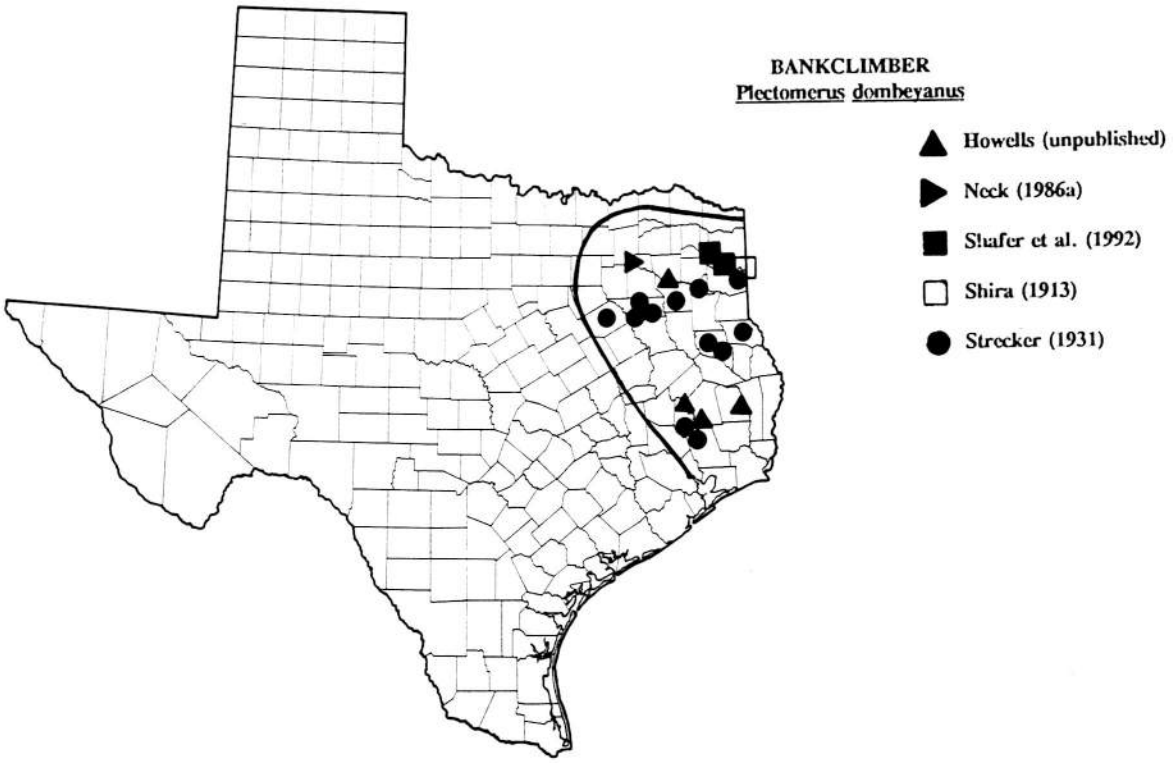
SPAWNING: Hoggarth (1988) reported glochidia in Louisiana in July; Harris and Gordon (undated) suggested bankclimber was probably a short-term breeder.

GLOCHIDIA: Shell subelliptical, 0.223-0.231 mm shell length, 0.238-0.259 mm shell height, 0.130-0.135 mm dorsally along the hinge line, with lanceolate micropoints in broken rows along the ventral margin (Hoggarth 1988).

HOSTS: Unreported.

ECONOMIC IMPORTANCE: Although not generally taken by the shell-button industry earlier in the century (Oesch 1984), bankclimber does produce pearls (Coker 1919) and subsequently represented one of the primary species supporting the pearl rush in Caddo Lake and adjacent waters in the early 1900s (Shira 1913), and earlier (Kunz 1897). None of the musselers surveyed in 1992 indicated they harvested this species, including those who otherwise collected Tampico pearlymussels (Cyrtonaias tampicoensis) for their purple-nacred shells (Howells 1993).

COMMENTS: This species has apparently been introduced successfully outside its native range into eastern North America (R. Knaub, Clemson University; pers. comm.).


BANKCLIMBER
Plectomerus dombeyanus
Howells (unpublished)
Neck (1986a)
Shafer et al. (1992)
Shira (1913)
Strecker (1931)

Soft Tissues: Unreported.

HABITAT: Streams (Strecker 1931).

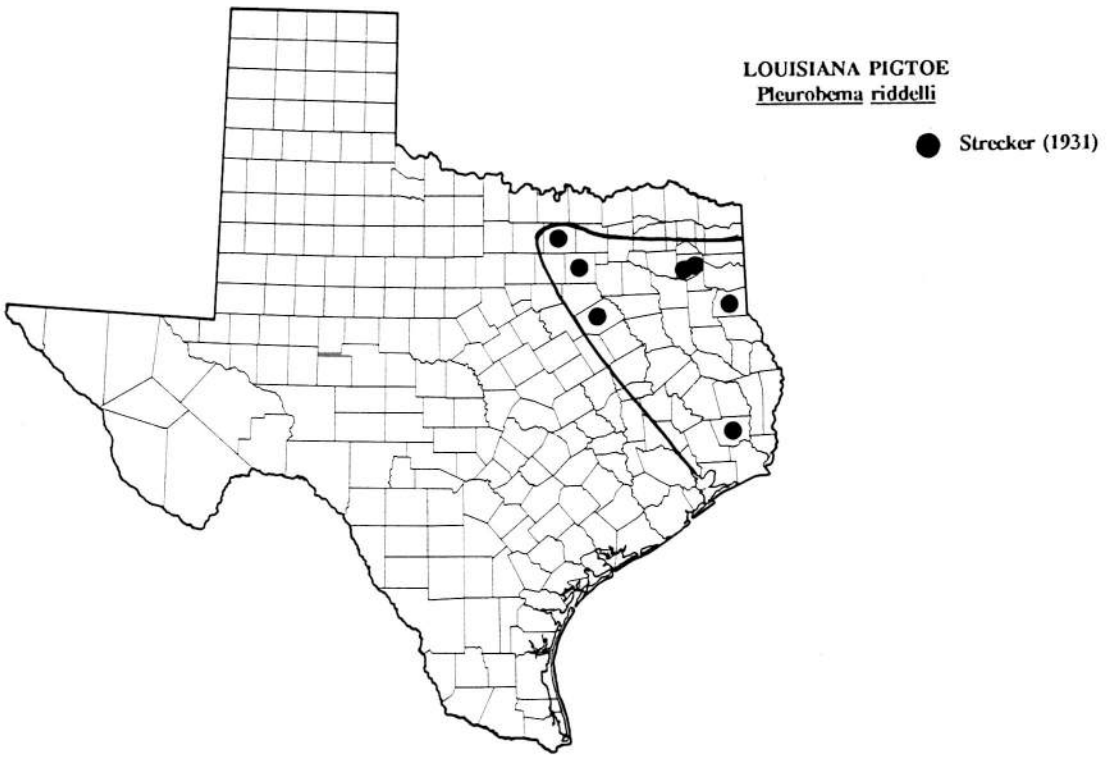
SPAWNING: Unreported.

GLOCHIDIA: Unreported.

HOSTS: Unreported.

ECONOMIC IMPORTANCE: None recognized; however, harvest of other pigtoe species could collectively include this species as well, except for its small size and general rarity.

COMMENTS: Type locality on the Trinity River at Dallas has undergone environmental modifications and general degradation; Strecker (1931) indicated the species may be extinct at the type locality. Athearn (1970) considered it as one of the most endangered naiads in Texas, and Simpson (1914) reported it as rare even earlier. Louisiana pigtoe is not listed as endangered or threatened on either Federal or TPWD lists; however, the American Fisheries Society considers it of special concern (Williams et al. 1993).



TEXAS HORNSHELL
Popenaias popei

Texas hornshell (Popenaias popei): Pecos River, Texas, July 1968; 67 mm shell length; TUC.

OTHER COMMON NAMES: Hornshell.

SYNONYMY: (Simpson 1914; Strecker 1931).

Unio popeii Lea 1857
Unio verae-pacis Tristam 1863 (probably)
Unio popei, Sowerby 1868
Margaron popeii Lea 1870
Unio ravistellus var. verae-pacis von Martens 1901
Lampsilis popei, Pilsbry 1909
Elliptio popei, Ortmann 1912
Popenaias popei (Lea 1857)

DISTRIBUTION: Occurs in the Rio Grande from Falcon Breaks to the Pecos River (Neck 1984), with an additional specimen taken in 1992 at the confluence of San Francisco Creek in the Big Bend area [RGH]; the Devils River, Texas, and Rio Salado, Mexico (Simpson 1914). Murray (1975) reported a population at Fort Clark Springs in Kinney County had been extirpated due to removal of aquatic vegetation; additionally, paving portions of this spring and chlorination in conjunction with its use as a swimming pool no doubt prevent repopulation.

DESCRIPTION: (Simpson 1914; Burch 1973).

Size: To 116 mm shell length and 43 mm shell height [RGH].

Shell: Elongate and subtrapezoidal; compressed, greatest diameter at or just behind the center, length to height ratio 1.8 or greater; narrowed anteriorly and centrally, wider posteriorly; rounded anteriorly, nearly straight to slightly concave ventrally, dorsally nearly straight, gently rounded to somewhat truncated posteriorly; posterior ridge double and widening posterio-ventrally; posterior slope broad and shallow; beaks low but sharp, beak cavities shallow and with dorsal pits; dull externally.

Shell Teeth: Left valve with two small to very small pseudocardinal teeth, anterior left tooth often higher and more pointed than the posterior tooth which is lower, more rounded and more elongate; right valve with a single small pseudocardinal tooth, but occasionally with a second smaller tooth as well; lateral teeth long, low, and curved to nearly straight, dorsal left tooth leans toward the hinge line.

External Color: Dark brown to smoky olive-green; may be faintly rayed when young; often eroded at beaks.

Internal Color: White to dull purplish-gray.

Soft Tissues: Unreported.

HABITAT: Unreported.

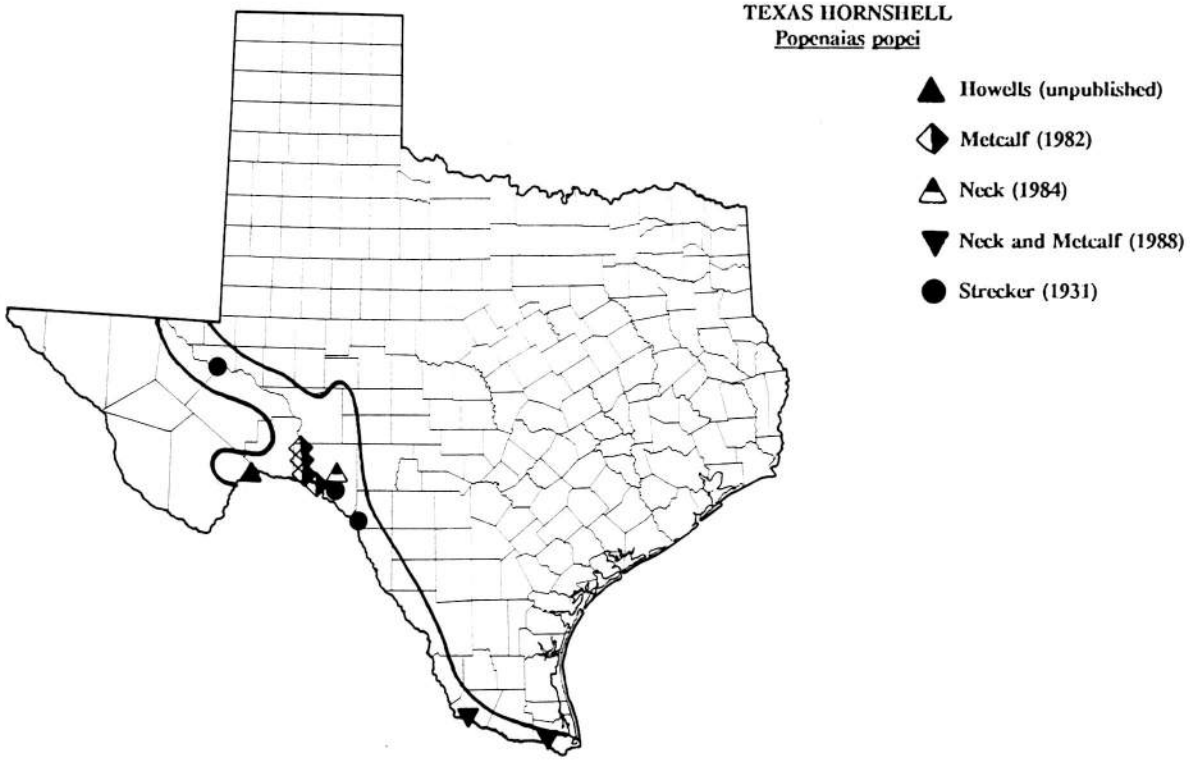
SPAWNING: Ortmann (1912) speculated Texas hornshell may be a winter, tachytictic breeder.

GLOCHIDIA: Unreported.

HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

COMMENTS: Texas hornshell was considered scarce by Strecker (1931), and as rare and endangered by Stansbery (1971). This species is not listed as either threatened or endangered on federal or TPWD lists; however, its omission may only reflect absence of study. The American Fisheries Society considers this species threatened (Williams et al. 1993). Loss of habitat and water quality in the lower Rio Grande suggest the species may deserve additional attention.



TEXAS HEELSPLITTER
Potamilus amphichaenus

Texas heelsplitter (Potamilus amphichaenus): B.A. Steinhagen Reservoir, Tyler County, Texas, December 1993; 111 mm shell length; TPWD.

OTHER COMMON NAMES: Heelsplitter.

SYNONYMY: (Simpson 1914; Strecker 1931; Neck 1986a; Hoggarth 1988).
Unio amphichaenus Frierson 1898
Proptera amphichaena Frierson 1898
Potamilus amphichaenus (Frierson 1898)
Lampsilis amphichaena, Simpson 1914
Lastena amphichaena (Frierson 1898)

DISTRIBUTION: Present in the Sabine, Neches, and Trinity river systems; not known from the San Jacinto River; specimens reported in the Brazos River drainage are of questionable identity.

DESCRIPTION: (Burch 1973; Littleton 1979; Neck 1986a; RGH).

Size: Reported to 177 mm shell length [RGH].

Shell: Elongate, length to height ratio 1.5 or more; thin; inflated; small, poorly-developed wing sometimes present above the distal end of the lateral teeth, often absent; curved anteriorly, gently curved ventrally, straight to slightly curved dorsally, and somewhat centrally pointed posteriorly; beaks only slightly raised above hinge line, beak cavities shallow; posterior ridge broad and low; with a narrow gape at the anterior margin and a larger gape just above the posterior margin; externally relatively smooth except for fine growth lines.

Shell Teeth: Two left pseudocardinal teeth compressed, lamellar, anterior tooth subrectangular in some specimens, only slightly elevated; posterior tooth low, elongate, poorly defined, only slightly raised above hinge line; single right pseudocardinal tooth compressed, gently rounded, sometimes slightly rough anteriorly; lateral teeth moderately long, compressed, moderately high, may be striated longitudinally.

External Color: Tan to brown on beaks, becoming much darker brown distally; disk center smooth and shiny.

Internal Color: Bluish-white or bluish-purple with color more intense dorsally and silvery-white ventrally; iridescent.

Soft Tissues: Dirty-white to grayish-white.

HABITAT: Requirements are poorly reported and ill-known. Neck (1986a) reported Texas heelsplitter from quiet waters on sand and mud. Specimens taken at B.A. Steinhagen Reservoir, Jasper and Tyler counties, Texas, were found in mud and sand [RGH]. Collections of specimens in reservoirs suggests toleration of impounded waters [RGH, RWN].

SPAWNING: Hoggarth (1988) obtained glochidia from a preserved specimen taken on the Texas-Louisiana border in mid-July; a living specimen obtained 29 December 1993 from B.A Steinhagen Reservoir, Jasper County, Texas, was not reproductively active.

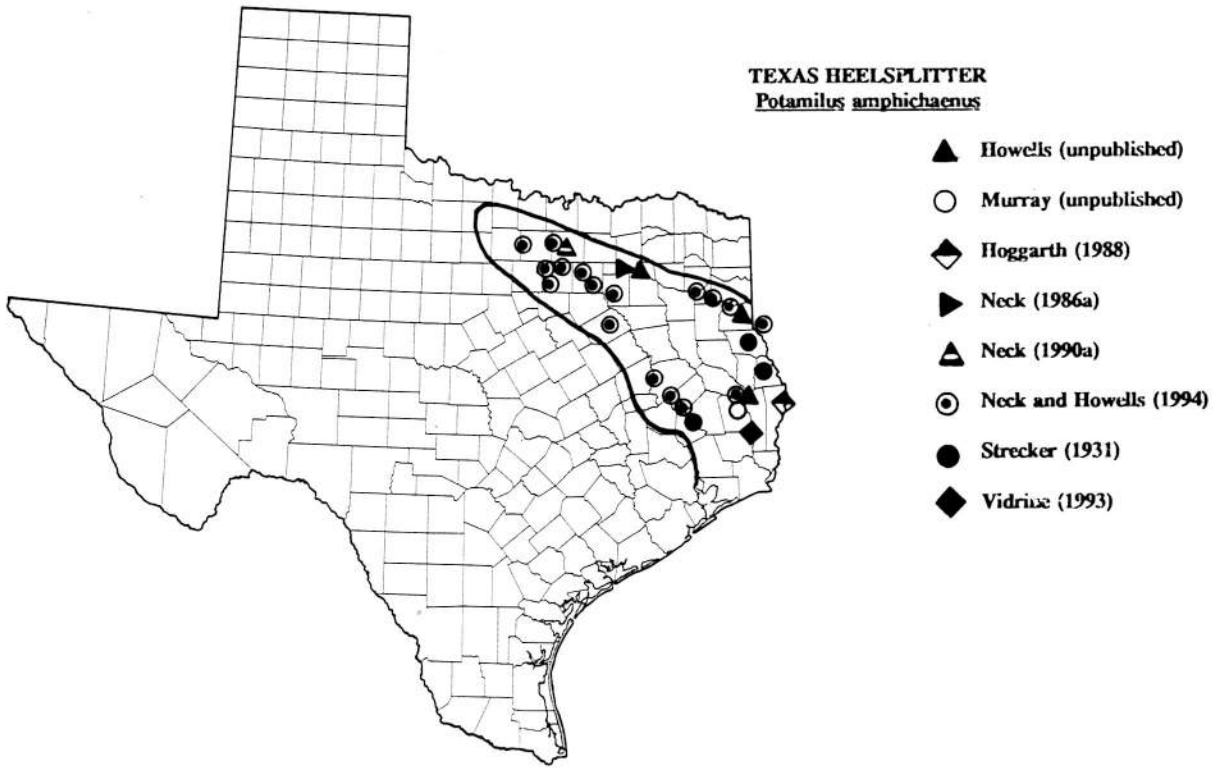
GLOCHIDIA: Shell axe-head shaped, 0.111-0.113 mm shell length, 0.170-0.171 mm shell height, 0.040-0.041 mm dorsally along the hinge line, small dorsal alae, loose-looped sculpturing on valves, and with lamellar micropoints in vertical rows of the valve flange (Hoggarth 1988).

HOSTS: Unreported.

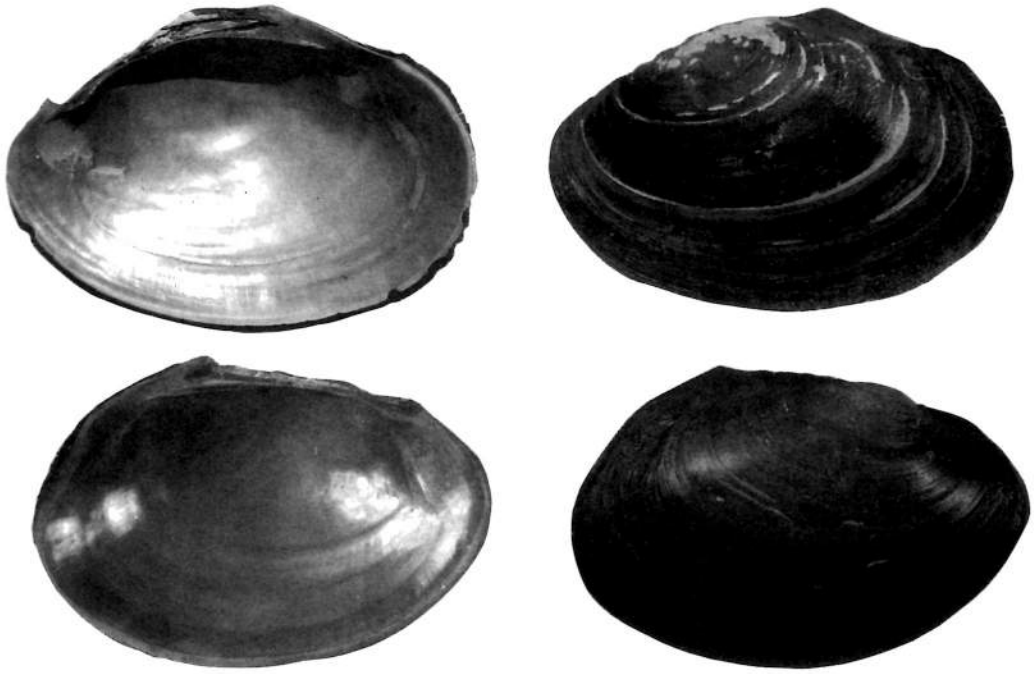
ECONOMIC IMPORTANCE: None.

COMMENTS: Texas heelsplitter could be confused with fragile papershell (Leptodea fragilis) and pink papershell (Potamilus ohiensis). Length to height ratio less than 1.5 in fragile papershell and pink papershell, and both are less inflated (Burch 1973). Neck (1986a) indicated Texas heelsplitter differed from pink papershell by (1) the presence of a pallial sinus posteriorly, (2) a noticeable intervalve gap truncated posteriorly, (3) a ventral margin which is more flattened, (4) a dark brown epidermis, and (5) being less compressed laterally.

This is an extremely rare species. Only about 150 specimens have been reported since the species was described in 1898 and only two living individuals appear to have been taken within the last 15 years (although several very recently-dead shells have been documented). The American Fisheries Society considers this species of special concern (Williams et al. 1993).



PINK PAPERSHELL
Potamilus ohiensis



Pink papershell (Potamilus ohiensis): Top Eagle Mountain Reservoir, Tarrant County, Texas, May 1992; 113 mm shell length; TPWD. Bottom Pine Creek, Lamar County, Texas, August 1993; 91 mm; TPWD.

OTHER COMMON NAMES: Razorback, pink heelsplitter, fragile heelsplitter.

SYNONYMY: (Murray and Leonard 1962; Starrett 1971; Oesch 1984; Hoggarth 1988).

Anodonta ohioensis Rafinesque 1820
Symphynota laevissima Lea 1830
Unio laevissimus, Call 1885
Lampsilis laevissima, Scammon 1906
Proptera laevissima (Lea), Ortmann 1912
Leptodea laevissima, Goodrich and van der Schalie 1944
Potamilus ohiensis Rafinesque 1820, Morrison 1968 (see Starrett 1971)
Lastena ohiensis (Rafinesque 1820)

Oesch (1984) and Gordon (1989) provided a discussion of Starrett's (1971) synonymy of ohiensis = laevissima. The species name has been spelled "ohioensis" and "ohiensis" with the latter being used by Turgeon et al. (1988) in the American Fisheries Society listing.

DISTRIBUTION: Previously reported from the Brazos, Sabine, and Red river drainages; found by TPWD in Eagle Mountain Reservoir, Tarrant County, Texas, in 1992 representing presence in the Trinity River basin.

DESCRIPTION: (Murray and Leonard 1962; Buchanan 1980; Oesch 1984; Fuller 1985).

Size: To 141 mm shell length in Texas (Neck 1989a); also reported as 106 mm in Missouri (Oesch 1984), 165 mm in Kansas (Murray and Leonard 1962), and 178 mm in the northcentral states (Cummings and Mayer 1992).

Shell: Oblong, ovate to elliptical in shape; thin, often cracks when dried; may be strongly alate posteriorly and occasionally with a small anterior wing, but wings often eroded partially or totally away; generally compressed, umbos slightly inflated; dorsal margin generally straight (except wing), curved anteriorly, posteriorly, and ventrally, sometimes nearly straight ventrally; beaks narrow, low and not raised above hinge line, beak cavity shallow; posterior ridge broad, rounded and barely noticeable; low concentric growth rings sometimes apparent; exterior may be more highly polished in northern populations than locally. Additionally, paired valves may have a gap at both ends where the foot extends anteriorly and water siphons extend posteriorly (Neck 1989a).

Shell Teeth: Two left pseudocardinal teeth, thin, lamellate, divergent and poorly developed; single right pseudocardinal tooth, thin, long; lateral teeth short, curved, and sometimes poorly developed, right valve tooth sometimes high.

External Color: Shiny; tan, brown, reddish-brown, olive-green, to black.

Internal Color: Pale pink to purple and mauve; iridescent.

Soft Tissues: Tan to buff in color; pseudosiphons often lengthy.

HABITAT: Pink papershell often occurs in shallow, flowing waters (Oesch 1984). Murray and Leonard (1962) reported it typical of sand and mud bottoms in large rivers with good currents, but not restricted to high-flow situations. Buchanan (1980) found it on silt, at depths from 2.5-14.2 cm, and in still waters. Neck (1982b) reported it as requiring moving waters and difficult to maintain in quiet-water aquaria. However, a specimen taken in Eagle Mountain Reservoir suggests at least some tolerance for reservoir environments [RGH]. Fuller (1985) indicated pink papershell to be tolerant of environmental alteration, including impoundment.

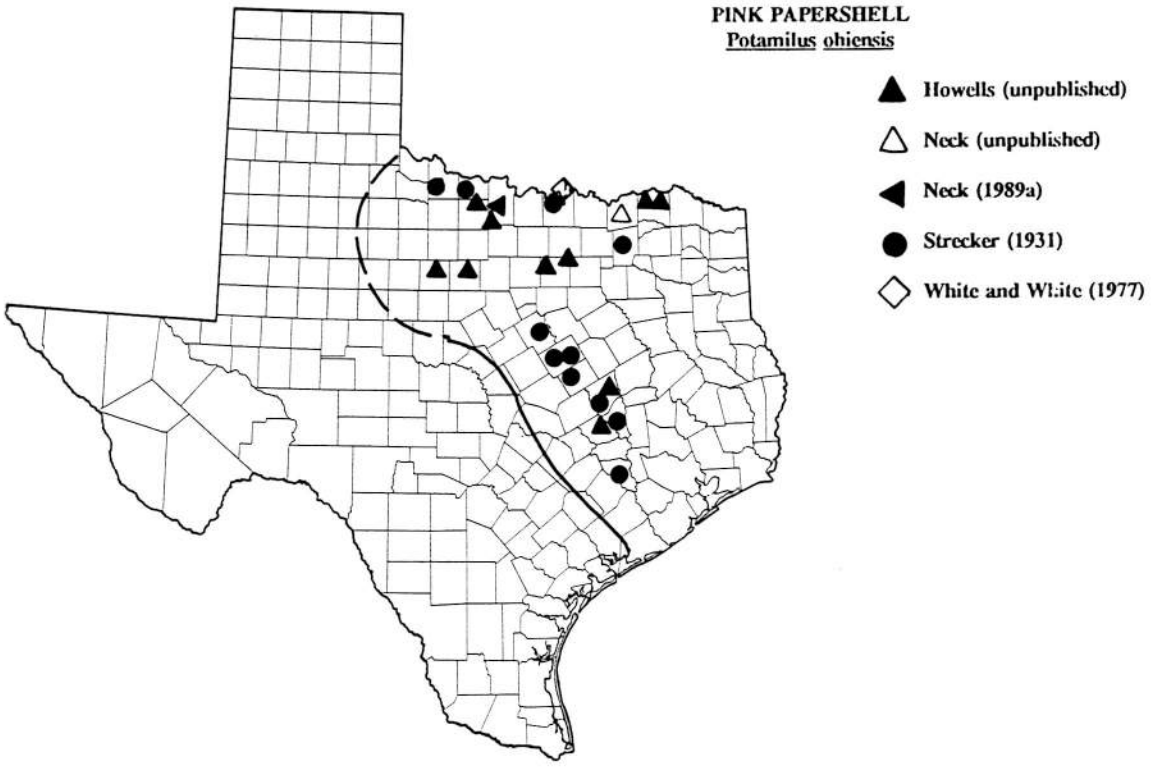
SPAWNING: Surber (1912) reported gravid females in April, June, and September; Hoggarth (1988) found glochidia in September; and Oesch (1984) listed it as a long-term, bradytictic breeder.

GLOCHIDIA: Shell small, axe-head or celtiform in shape, 0.100 x 0.155 mm (Utterback 1915-16). Glochidia are released in conglutinate masses (Oesch 1984). Hoggarth (1988) described glochidia as axe-head shaped, 0.120-0.126 mm shell length, 0.170-0.175 mm shell height, 0.042-0.050 mm dorsally along the hinge line, with small alae, and a large lateral gape; he further questioned previous descriptions which included hooks or spines which are actually lacking.

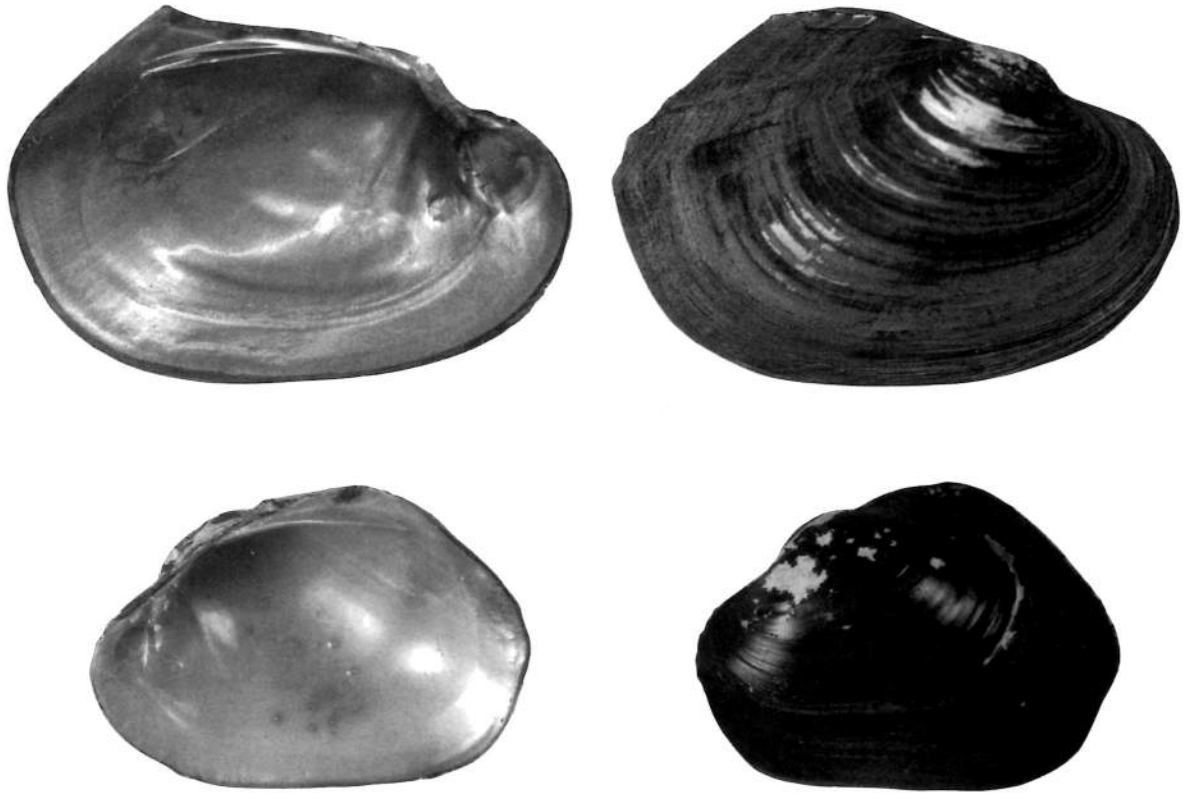
HOSTS: Freshwater drum (Aplodinotus grunniens) and white crappie (Pomoxis annularis) (Surber 1913; Fuller 1978).

ECONOMIC IMPORTANCE: None.

COMMENTS: Although moderate in size and having an attractively colored nacre, its thin, fragile shell precluded value in commercial harvest. Strecker (1931) indicated reports of pink heelsplitter (Potamilus alatus) in Texas may actually represent pink papershell; pink heelsplitter is not known from the state.


PINK PAPERSHELL
Potamilus ohiensis
Howells (unpublished)
Neck (unpublished)
Neck (1989a)
Strecker (1931)
White and White (1977)

BLEUFER
Potamilus purpuratus



Bleufer (Potamilus purpuratus): Top Nasworthy Reservoir, Tom Green County, Texas, August 1992; 114 mm shell length; TPWD. Bottom Pine Creek, Lamar County, Texas, August 1993; 92 mm; TPWD.

OTHER COMMON NAMES: Bluefer, blufer, purple shell, purple shell mussel, pink, purple pocketbook, heelsplitter (term common among San Angelo musselers), blooper, blue mucket, blue hen.

SYNONYMY: (Strecker 1931; Murray and Leonard 1962; Oesch 1984)
Unio purpurata Lamarck 1819
Unio purpuratus Lamarck, Singley (see Strecker 1931)
Unio coloradoensis Lea 1856
Lampsilis purpuratus, Simpson 1900
Lampsilis purpurata, Scammon 1906
Proptera purpurata (Lamarck), Ortmann 1912
Proptera purpurata (Lamarck), Murray and Leonard 1962
Potamilus purpuratus (Lamarck), Oesch 1984

DISTRIBUTION: Present from the Guadalupe River basin into systems to the north and east; found in Lake Corpus Christi, Live Oak County, Texas, in 1993 (introduction) [RGH]. Early authorities confused bleufer

with Tampico pearlymussel (Cyrtonaias tampicoensis) accounting for reports from extreme southwestern locations.

DESCRIPTION: (Murray and Leonard 1962; Oesch 1984; RGH).

Size: To 178 mm in shell length in Texas [RGH]; also reported to 176 mm in Missouri (Oesch 1984), and 227-265 mm in Kansas (Murray and Leonard 1962).

Shell: Ovate to oblong or quadrate in shape; often stout and thick in eastern populations, but thinner in some more western populations; slightly inflated to inflated, occasionally strongly so in eastern areas, but usually compressed in western localities; often relatively alate in western specimens but largely non-alate in eastern individuals; dorso-ventrally deep-bodied posteriorly, but often relatively narrow anteriorly; dorsal margin slightly curved (excluding wing in alate forms), rounded anteriorly, ventral margin often nearly straight in females and gently rounded in males, posteriorly rounded in males and more truncated in females; posterior ridge rounded and not well defined, one or three additional ridges may also be present on the posterior slope and may continue to the posterior margin where they appear as projecting points (obscure in larger, older individuals); beaks narrow, raised above hinge line, usually heavily eroded, beak cavities deep; externally growth rings apparent on some specimens; the posterio-ventral margin in some individuals often unmatched between valves creating a gap that cannot be fully closed.

Shell Teeth: Two left pseudocardinal teeth erect, emarginate; posterior-most tooth pointed to nearly square, striated, flattened, and the anterior-most tooth usually tilted forward, round-pointed to rounded, striated or pitted; anterior tooth almost always completely anterior to the beak; single right pseudocardinal tooth pointed, with a thin anterior denticle; lateral teeth moderate to short, slightly curved, higher in the right valve, ventral left lateral tooth often shorter than the dorsal tooth.

External Color: Typically dark brown to black, decidedly reddish-brown in western populations; rayless or with greenish-brown rays.

Internal Color: Typically dark purple; specimens from western localities often deep-rose colored, less frequently purple, rarely pinkish-orange or peach.

Soft Tissues: White to tan in color. Marsupia reported as restricted to the posterior halves of the outer gills (Oesch 1984); however, gravid specimens obtained in Nasworthy Reservoir, Tom Green County, Texas, had marsupia completely filling both outer gills fully; inner gills sterile [RGH].

HABITAT: Bleufer occurs in deep-water streams or quiet pools with mud bottoms (Murray and Leonard 1962); on fine to medium gravel interspersed with mud (Oesch 1984). Specimens in Texas occur in large or smaller reservoirs or streams and rivers with slow to moderate currents, or in slow-moving sloughs often on mud or gravel at depths from ca. 0.5 to 3.0 m [RGH].

SPAWNING: Spawning has been reported as largely unknown by Oesch (1984) and as long term by Harris and Gordon (undated); specimens taken from Nasworthy Reservoir, Tom Green County, contained glochidia in October, November, and January and in June in B.A. Steinhagen Reservoir, Jasper County [RGH]. Hoggarth (1988) obtained glochidia from a female collected below the dam at Lake Whitney, Bosque and Hill counties, in March. Littleton (1979) took gravid females in the Navasota River, Texas, in June, and considered it bradytictic. In Texas, the smallest gravid female examined from Nasworthy Reservoir, Tom Green County, was 81.7 mm shell length and 60.9 mm shell height [RGH], with 120 mm shell length as the smallest mature female from the Navasota River (Littleton 1979).

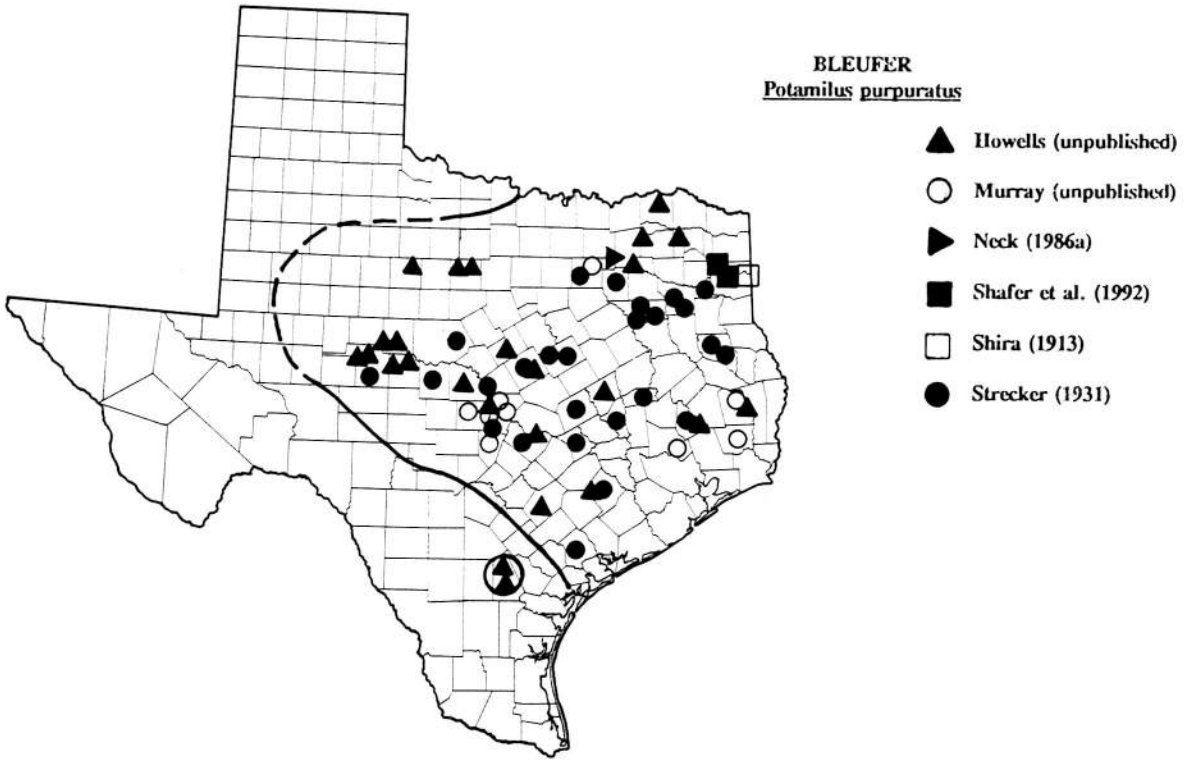
GLOCHIDIA: Shell axe-head shaped (Utterback 1915-16). Hoggarth (1988) described glochidia shells as lingulate axe-head shaped, 0.190-0.200 mm shell length, 0.347-0.356 mm shell height, 0.100-0.109 mm dorsally along the hinge line, anterior and posterior margins only slightly curved, small dorsal alae, lateral valve gape wide, and with lanceolate hooks on the lateral margins of the valve flange. Glochidia from Nasworthy Reservoir females were slightly smaller (about 0.110 mm shell length), but were otherwise identical [RGH].

HOSTS: Freshwater drum (Aplodinotus grunniens) (Surber 1915).

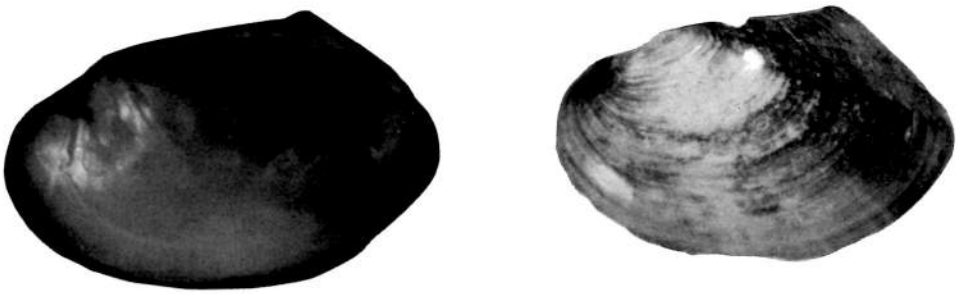
ECONOMIC IMPORTANCE: Bleufers were previously not taken to any extent by the button industry, or more recently by the pearl-shell musselers. Bleufers do occasionally produce quality pearls and have been taken to a limited extent by the curio, shell chip, and jewelry industries.

COMMENTS: Confusion of bleufers with Tampico pearlymussels (Cyrtonaias tampicoensis) existed in some older literature accounts for reports of bleufers from extreme southwestern localities in Texas, and continues to some extent at present. Pseudocardinal teeth are usually more massive in Tampico pearlymussels, less likely to be compressed, and less likely to lean anteriorly. Tampico pearlymussels are usually most posteriorly pointed ventrally (below the midline), but bleufers are usually most posteriorly pointed centrally or dorsally (above the midline). Tampico pearlymussels may be slightly alate in juveniles, but bleufers are often more strongly winged, especially in western populations. Tampico pearlymussels are dorso-ventrally deeper bodied anterior to the beak (less so in bleufers). In coloration Tampico pearlymussels are most often purple nacred, less frequently pink, salmon, or white; bleufers are usually purple nacred in eastern Texas specimens and more often deep-rose colored in western individuals (though examples with purple nacres do occur in the Concho River drainage); both species have occasionally yellow-orange or peach-colored nacres. Although bleufers can produce gem-quality pearls, many musselers (especially in central and western areas) often shun bleufers and only seek pearls in Tampico pearlymussels.

NOTE: Although early reports of bleufer in the Rio Grande were based on misidentified Tampico pearlymussels, TPWD collected bluefers in Amistad Reservoir and the Devils River, Val Verde County, in 1994 and 1995. Identity was confirmed with electrophoretic analysis. Specimens ranged in size from small juveniles to large, old adults. Absence from the fossil record and other recent collections suggests these may represent an introduced population.



SALINA MUCKET
Potamilus salinasensis



Salina mucket (Potamilus salinasensis): Rio Grande at San Francisco Creek, Brewster County, Texas, January 1992; 79 mm shell length; TPWD.

OTHER COMMON NAMES: Rio Grande heelsplitter.

SYNONYMY: (Neck 1982b; Neck and Metcalf 1988; Neck 1984)

Disconaias fimbriata Frierson 1907
Disconaias fimbriata, Neck 1982b
Potamilus fimbriatus (Frierson 1907), Neck and Metcalf 1988
Lampsilis salinasensis, Simpson 1908
Disconaias salinasensis, Simpson 1908
Disconaias salinasensis (Simpson), Neck 1984, Turgeon et al. 1988

Neck and Metcalf (1988) characterized the species as an enigmatic taxon whose generic placement was uncertain; the American Fisheries Society (Turgeon et al. 1988) listed it as Disconaias.

DISTRIBUTION: Occurs in the Rio Grande, south into Mexico; collected alive near Del Rio (Neck 1984). Shells recovered at the confluence of San Francisco Creek and the Rio Grande in the Big Bend area in 1992 [RGH]. Type locality given as Salinas River, Coahuila, Mexico, and the Valles River, Mexico, by Metcalf (1982); however, Simpson (1914) listed only the latter.

DESCRIPTION: (Metcalf 1982; RGH).

Size: Reported to 105 mm shell length (Metcalf 1982); specimens taken by TPWD in 1992 ranged from 80 to 95 mm in length [RGH].

Shell: Oval in shape, slightly elongate; some slightly deeper-bodied posteriorly; relatively thin-shelled (slightly thicker than pink papershell P. ohiensis) to slightly thick; solid; some specimens weakly alate posteriorly; dorsal outline nearly straight if uneroded to slightly curved (may be steep and enhance winged appearance), anteriorly curved, ventrally gently curved to almost straight, curved but somewhat centrally pointed posteriorly; posterior ridge weak, rounded, ill-defined; beaks only slightly above hinge line, beak cavities shallow; externally relatively smooth except for concentric growth rings.

Shell Teeth: Two left and one right pseudocardinal teeth thin, compressed, triangular, somewhat thicker in older specimens; lateral teeth long, slightly curved.

External Color: Tan to dark brown or black; some with moderately thin, dark brown rays posteriorly.

Internal Color: White to bluish-white; iridescent; one specimen from San Francisco Creek with a pale salmon tint.

Soft Tissues: Unreported.

HABITAT: This species has been described as adapted to lotic waters (Neck and Metcalf 1988); otherwise habitat requirements are poorly known.

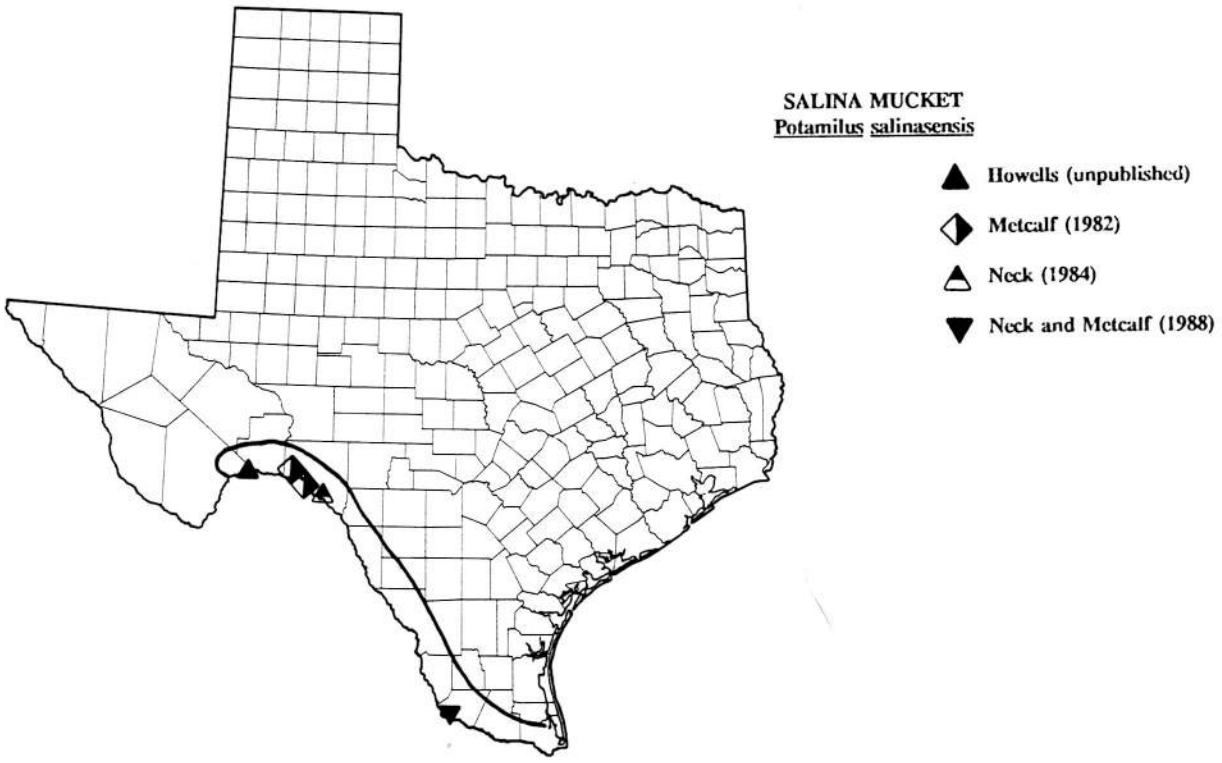
SPAWNING: Unreported.

GLOCHIDIA: Unreported.

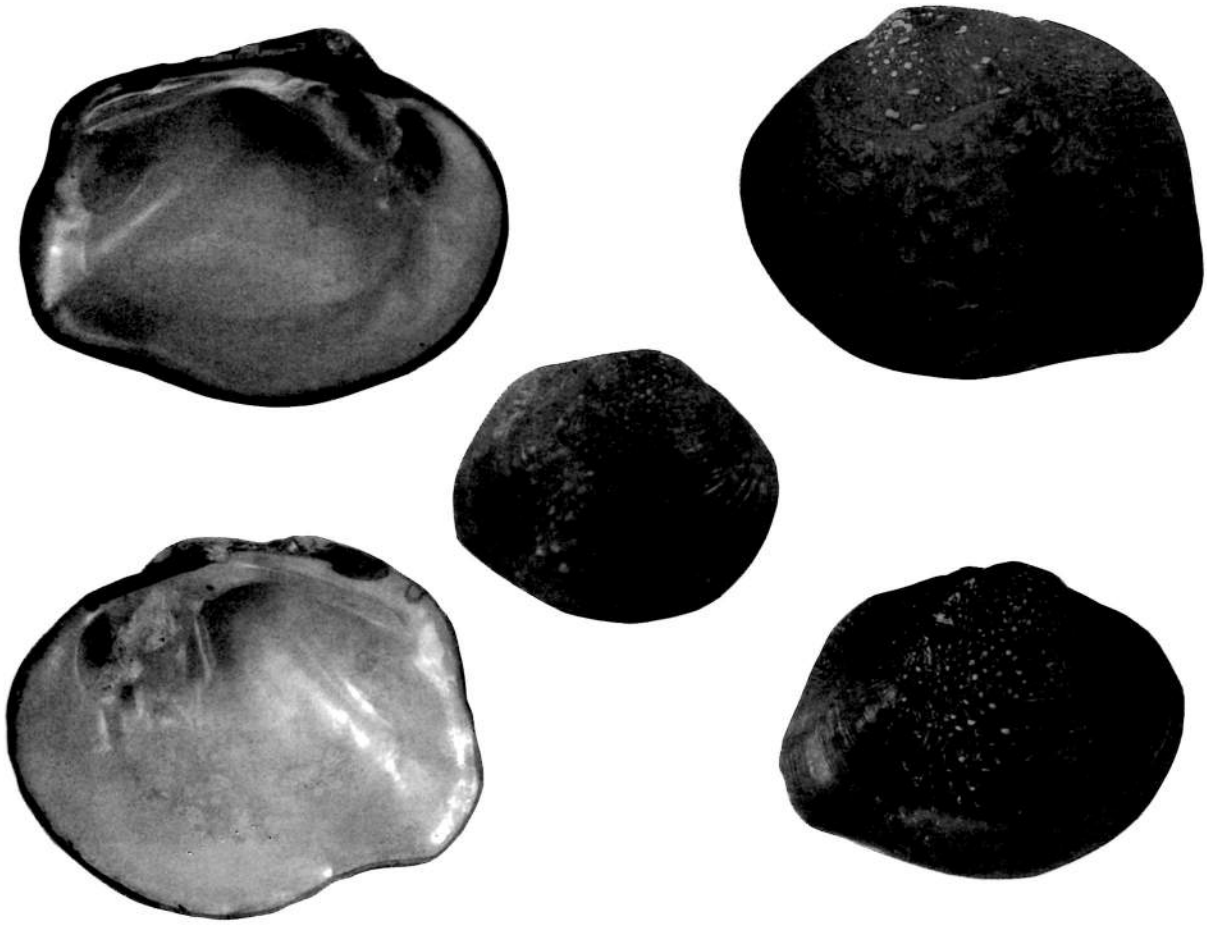
HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

COMMENTS: This species represents a unique form from border waters of Texas. If validly Disconaias, then it is the only representative of the genus in the U.S. Thinner-shelled, more-angular examples suggest similarity to other potamilid-type heelsplitters, but heavier-shelled, more-rounded specimens suggest "mucket" traits. Thin-shelled, alate form resembles to some extent a small fragile papershell (Leptodea fragilis) with a poorly developed wing [RGH]; heavier specimens are similar to bleufer (Potamilus purpuratus), but without the purple nacre (Neck and Metcalf 1988). The American Fisheries Society considers Salina mucket threatened (Williams et al. 1993).



SOUTHERN MAPLELEAF
Quadrula apiculata



Southern mapleleaf (Quadrula apiculata): Left and top right Nasworthy Reservoir, Tom Green County, August 1992; left 82 mm shell length, top right 101 mm; TPWD. Center and bottom right Elm Creek, Runnels County, Texas, August 1993; center 62 mm; bottom right 84 mm; TPWD.

OTHER COMMON NAMES: Greenie, mapleleaf.

SYNONYMY: (Strecker 1931; Neck 1982a).

Unio apiculatus Say 1829
Quadrula apiculata Say 1829
Quadrula apiculata (Say), Simpson 1900

DISTRIBUTION: Occurs in all major drainage systems.

DESCRIPTION: [RGH].

Size: To at least 118 mm shell length, probably slightly larger. Reports from musselers of specimens 130-175 mm are unconfirmed [RGH].

Shell: Quadrate; typically inflated, some specimens less so, others nearly globular; thin to very thick, especially at the beak, thinner ventrally; solid; rounded anteriorly and ventrally to where the posterior ridge reaches the margin (posterio-ventrally round-pointed, and sometimes concave anterior to the posterior ridge), curved

dorsally and posteriorly; beaks extend well above the hinge line, beak cavities deep; posterior ridge angular to broadly rounded, extending to the ventral margin; sulcus anterior to the posterior ridge shallow and poorly defined, nearly absent in some specimens; shell ornamentation consisting of small pimples covering the entire shell in juveniles to only the beak in large adults, pimples not restricted to vertical rows and only very rarely enlarged into larger pustules or drop-shaped lunules, rows of ridges present in the posterior field from the posterior ridge to the hinge; concentric growth rings typically apparent.

Shell Teeth: Two left pseudocardinal teeth large, triangular, often deeply grooved, and widely separated; single right pseudocardinal tooth large, massive, heavily grooved; a small, leaf-like denticle often present anteriorly, and sometimes posteriorly; lateral teeth straight to nearly straight; moderate in length; right lateral tooth sometimes heavily striated.

External Color: Yellow, greenish-yellow, to ocher in some smaller specimens, brown, gray, grayish-brown, or black in others and in larger individuals, rarely with green rays; concentric growth rings often displayed as bands of alternating colors; typically not glossy.

Internal Color: White.

Soft Tissues: White to off-white or tan; gills may be pale tan to dark brown.

HABITAT: The species occurs in flowing waters in rivers and streams, slow-moving canals, and still-water reservoirs on mud, mud and gravel, mud and sand, and mud, gravel, and cobble; it occurs to depths of at least 4.6 m, but often much less. Specimens found in a heated-water power-plant discharge canal were found completely buried, perhaps in an effort to avoid extremely warm temperatures. Sometimes found in beds of washboards (Megalonaias nervosa) or threeridges (Amblema plicata). Numerous large specimens (> 100 mm) were found in a mud-bottom canal at one TPWD fish hatchery at depths less than 1 m. Densities as high as $30/m^2$ were found in Cedar Creek Reservoir, Henderson County, Texas [RGH].

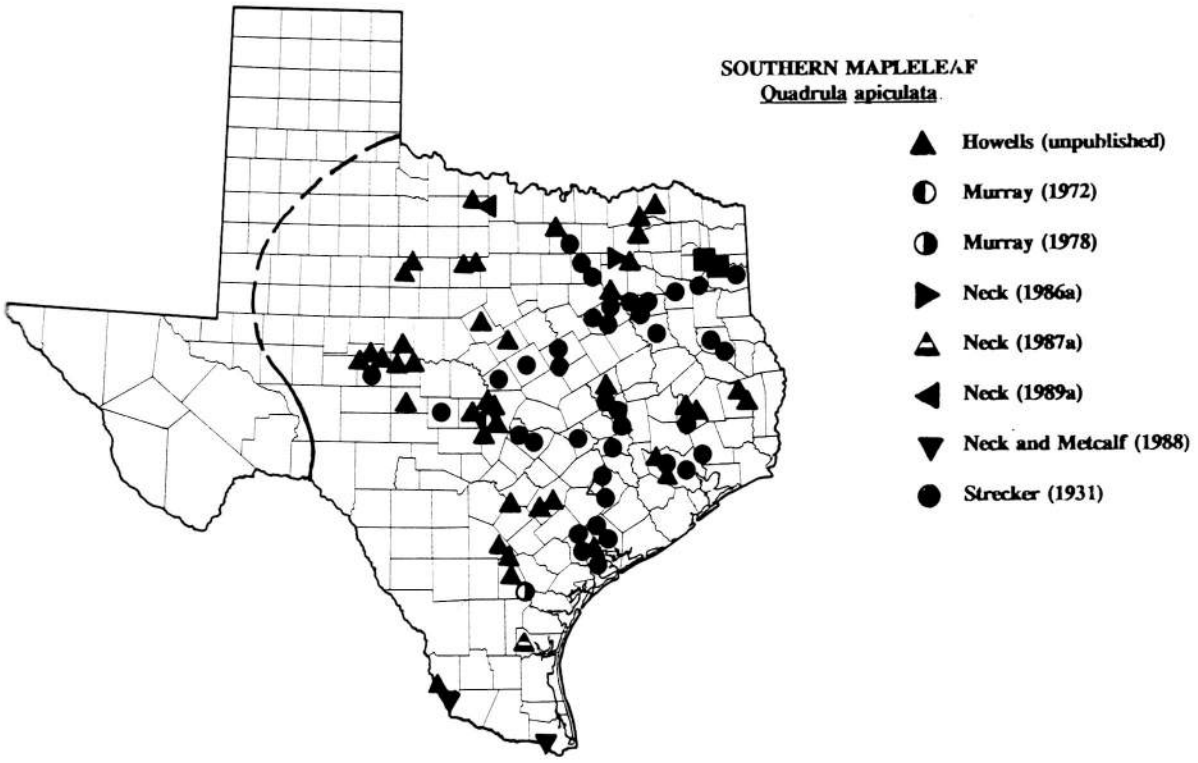
SPAWNING: Gravid females were found in the Neches River, Jasper County, Texas in early May; mature eggs were found in females from Cedar Creek Reservoir, Henderson County, and the Concho River, Concho County, Texas, in mid-June and in several females from Central Texas in July [RGH]. Littleton (1979) reported gravid females in July and August, with a minimum size for mature females of 38 mm shell length.

GLOCHIDIA: Shell very small, nearly round except for the straight hinge line, 0.077 x 0.065 mm, 0.022 mm along the hinge line, similar to mapleleaf (Quadrula) [RGH].

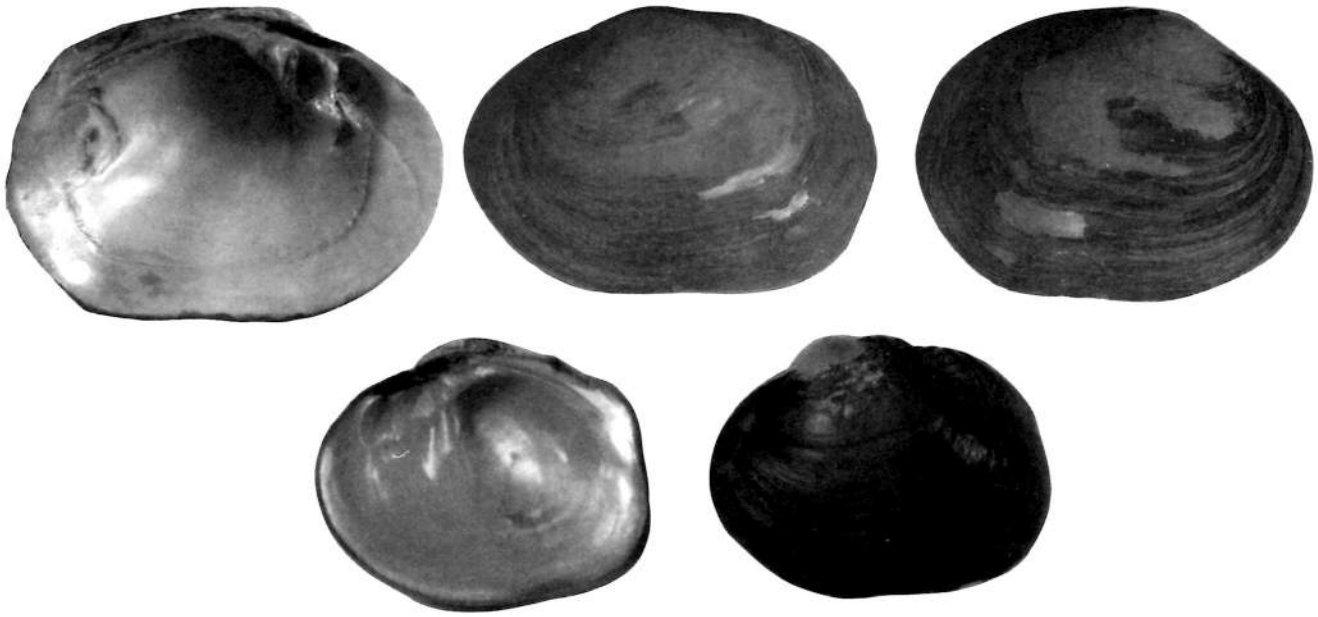
HOSTS: Unreported.

ECONOMIC IMPORTANCE: Southern mapleleaf is commercially important as a source of shell in the cultured pearl industry and one of the three species most frequently taken for that purpose along with washboards and threeridges. Although they do produce gem-quality pearls, few musselers specifically harvest southern mapleleafs in Texas in search of pearls. Southern mapleleaf was not reported as a major shell species of the button trade earlier in the century, but musselers may not have differentiated between it and mapleleaf.

COMMENTS: This species is probably most similar to mapleleaf which usually has larger pustules positioned in rows running from the beak to the ventral margin, has a well-defined sulcus anterior to the posterior ridge, and is restricted locally to drainages in eastern Texas.


SOUTHERN MAPLELEAF
Quadrula apiculata
Howells (unpublished)
Murray (1972)
Murray (1978)
Neck (1986a)
Neck (1987a)
Neck (1989a)
Neck and Metcalf (1988)
Strecker (1931)

GOLDEN ORB
Quadrula aurea



Golden orb (Quadrula aurea): Top San Saba River, Menard County, Texas, August 1992; 77 mm shell length; TPWD. Bottom Guadalupe River, Guadalupe County, Texas, May 1993; 38 mm; TPWD.

OTHER COMMON NAMES: None.

SYNONYMY: (Strecker 1931).
Unio aureus Lea 1859
Quadrula aurea (Lea), Simpson 1900

DISTRIBUTION: Occurs in the San Antonio, Guadalupe, Colorado, Brazos, Nueces, and Frio River systems.

DESCRIPTION: (Burch 1973; RGH).

Size: To at least 77 mm in shell length [RGH].

Shell: Subrectangular to broadly elliptical or slightly oblong, clearly longer than high, height about 80% (70.6-86.3%) shell length; moderately thick; solid; somewhat inflated; slightly curved dorsally, nearly straight ventrally and sometimes slightly concave or convex, rounded anteriorly, almost truncated posteriorly, very slightly pointed at the posterior ridge; beaks slightly inflated and not noticeably above hinge line to clearly above hinge line, beak cavities deep; posterior ridge broadly rounded and poorly developed, associated median sulcus lacking; externally usually smooth and unsculptured except for concentric growth rings, rarely with slight ridges posterio-dorsally to the posterior ridge.

Shell Teeth: Two left pseudocardinal teeth large, triangular or square, elevated, slightly compressed, lightly striated, often with a deep groove before the posterior-most tooth with a strong ridge at the bottom of the groove (matches a deep groove on the corresponding right pseudocardinal tooth), posterior-most tooth somewhat less elevated than the anterior tooth and subrectangular to rounded; two right pseudocardinal teeth, anterior tooth small, not highly elevated, compressed, posterior-most tooth large, elevated, subtriangular, deeply grooved centrally, with a deep groove behind and a large posterior denticle; two left lateral teeth, very slightly curved, not highly elevated; single right lateral tooth, ca. 40% shell length, slightly curved, moderately elevated, diagonally striated dorsally.

External Color: Tan, reddish-brown, orange-brown, or gray-brown.

Internal Color: White; iridescent posteriorly.

Soft Tissues: Off-white to light tan throughout [RGH].

HABITAT: Unreported. However, often absent from reservoirs built on rivers previously containing golden orb populations suggesting the species may be less tolerant of impoundment than southern mapleleaf (Q. apiculata). Shells taken on the San Saba River, Menard County, and Guadalupe River, Gonzales County, Texas, were found in sand and gravel; shells collected at Lake Corpus Christi, Live Oak County, Texas, were found in mud at the bases of inundated willows (Salix spp.).

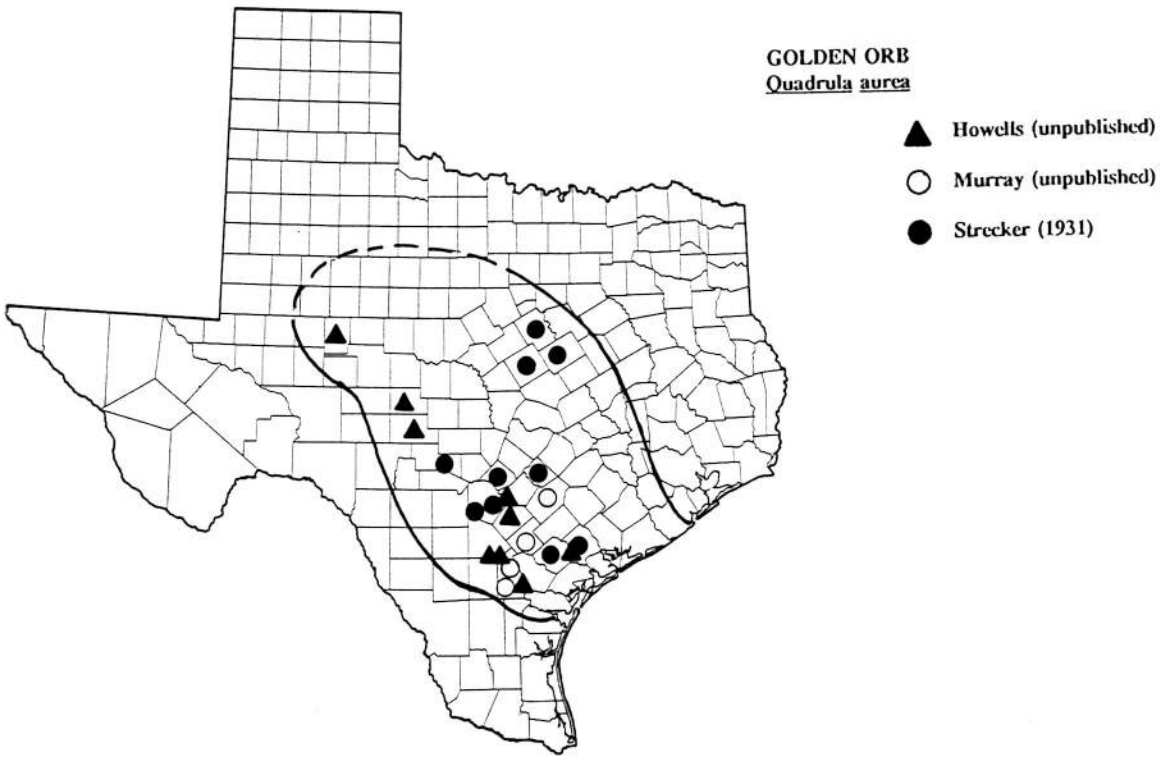
SPAWNING: Females with fertile eggs were found in Lake Corpus Christi in late August [RGH].

GLOCHIDIA: Unreported.

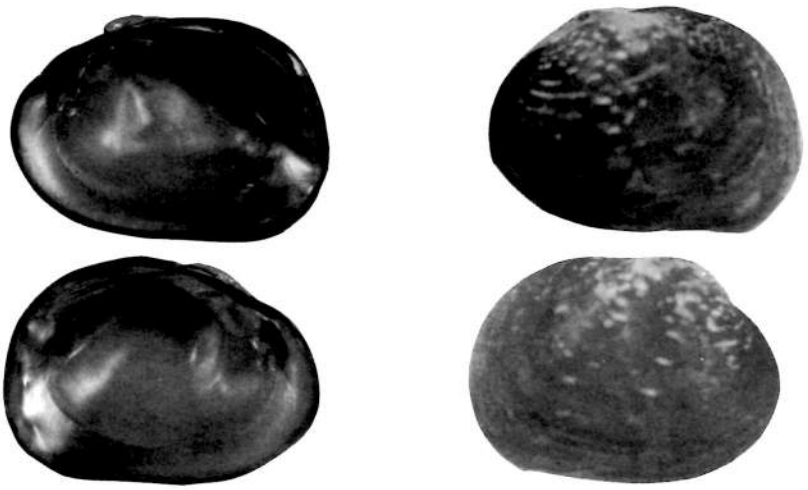
HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

COMMENTS: Subfossil shells taken from Indian shell mounds in the western portion of its range and collection of more-recent shells along river banks but failure to locate living specimens in 1992 or 1993 sampling by TPWD suggests this Central Texas endemic species may be declining [RGH]. The American Fisheries Society considers this species of special concern (Williams et al. 1993).



RIO GRANDE MONKEYFACE
Quadrula couchiana



Rio Grande monkeyface (Quadrula couchiana): Las Moras Creek, Kinney County, Texas, May 1898; 31 mm shell length; HMNS.

OTHER COMMON NAMES: None.

SYNONYMY: (Simpson 1914; Strecker 1931).
Unio couchianus Lea 1860
Magaron couchianus Lea 1870
Quadrula couchiana, Simpson 1900

DISTRIBUTION: Occurs in the Rio Grande; endemic, or probably so (Metcalf 1982; Neck 1984). Not reported by Neck and Metcalf (1988) in the lower Rio Grande. Two bleached valves in the U.S. National Museum were reportedly taken from Zavala County, Texas, in the Nueces River drainage and attributed to this species (Metcalf 1982) may be those of Texas pimpleback (Q. petrina) which is similar [RWN].

DESCRIPTION: (Simpson 1914; Metcalf 1982; RGH).

Size: Reported to 58 mm shell length and 47.5 mm in shell height by Metcalf (1982) and to 50 x 38 mm by Simpson (1914).

Shell: Subrhomboidal, generally nearly round to slightly oval; only slightly inflated; solid; valves slightly inequilateral; slightly curved dorsally, curved anteriorly, curved to gently curved ventrally (anterior to the posterior ridge), very slightly curved posteriorly above the posterior ridge, posterior ridge sometimes bluntly pointed where the posterior ridge(s) extend beyond the posterio-ventral margin; beaks full and elevated above hinge line, beak cavities deep; posterior ridge usually moderately developed and often double; externally relatively smooth except for fine growth lines, or sometimes more or less covered with pustules.

Shell Teeth: Two left and one right pseudocardinal teeth are elevated, uneven, and ragged; lateral teeth typical quadrulid form; right lateral tooth may be single or slightly double.

External Color: Ashy-brown; greenish in young.

Internal Color: White; iridescent silvery posteriorly.

Soft Tissues: Unreported.

HABITAT: Unreported.

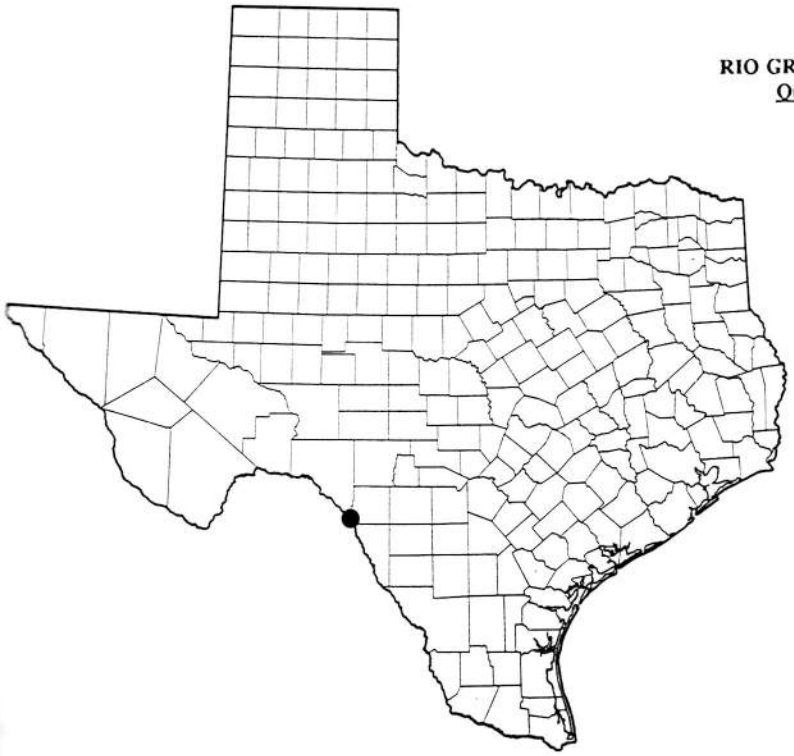
SPAWNING: Unreported.

GLOCHIDIA: Unreported.

HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

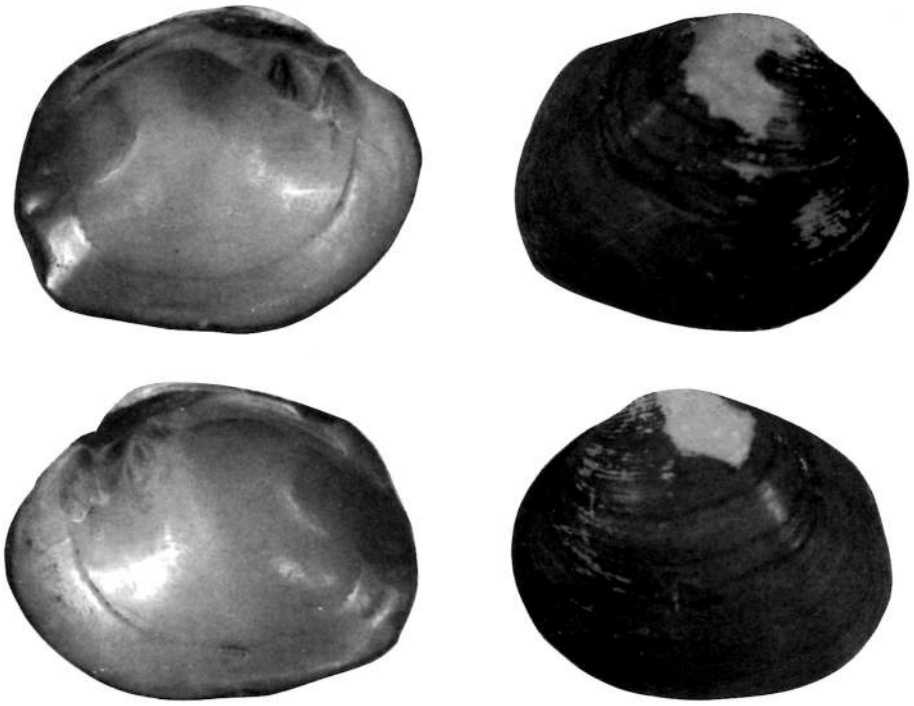
COMMENTS: This species is typically found as fossils in Texas (Metcalf 1982); however, living specimens were reported from the Rio Conchos, Chihuahua, Mexico (Neck 1984). Metcalf (1982) indicated Rio Grande monkeyface has little resemblance to southern mapleleaf (Q. apiculata) but was more like Texas pimpleback from central Texas. Rio Grande populations apparently show great variability, some with pronounced posterior ridges and a less well developed median ridge with a sulcus between, others low posterior ridges and little or no ornamentation. The American Fisheries Society considers this species endangered (Williams et al. 1993).



RIO GRANDE MONKEYFACE
Quadrula couchiana

● Strecker (1931)

SMOOTH PIMPLEBACK
Quadrula houstonensis



Smooth pimpleback (Quadrula houstonensis): Brazos River, Brazos County, Texas, 1949; 49 mm shell length; HMNS.

OTHER COMMON NAMES: Houston pimpleback, southern pimpleback.

SYNONYMY: (Simpson 1914; Strecker 1931).
Unio houstonensis Lea 1859
Margaron houstonensis Lea 1870
Quadrula houstonensis Lea, Simpson 1900

Although Q. houstonensis is recognized as valid by the American Fisheries Society (Turgeon et al. 1988), specimens in museum collections suggest it may be a "catch-all" species for otherwise atypical quadrulids [RWN]. Ultimate taxonomic disposition may need to await electrophoretic analysis.

DISTRIBUTION: Occurs in the Colorado, Brazos, and San Jacinto River drainage basins. Simpson (1914) also listed it from southern Arkansas.

DESCRIPTION: (Simpson 1914; Strecker 1931).

Size: To 66 mm shell length and 59 mm in height (Simpson 1914).

Shell: Rounded and blunt, subrhomboidal to subquadrate, length and height often near equal; heavy and globular; inflated; solid; rounded anteriorly, ventrally curved to nearly straight, truncated dorsally, posteriorly truncated or nearly so; beaks full and high, beak cavities deep; posterior ridge well developed, narrowly rounded or slightly angular; externally smooth or with a few small pustules, sculpturing usually minute.

Shell Teeth: Two left and one right pseudocardinal teeth strong and often split; lateral teeth typical of quadrulids;

right valve teeth single or weakly double.

External Color: Yellow-buff, yellow-green in young, to ashy-brown in older specimens; sometimes faintly rayed.

Internal Color: Silvery-white.

Soft Tissues: Off-white to tan.

HABITAT: This species occurs in mixed mud, sand, and fine gravel in the Little Brazos River, Robertson County, Texas [RGH].

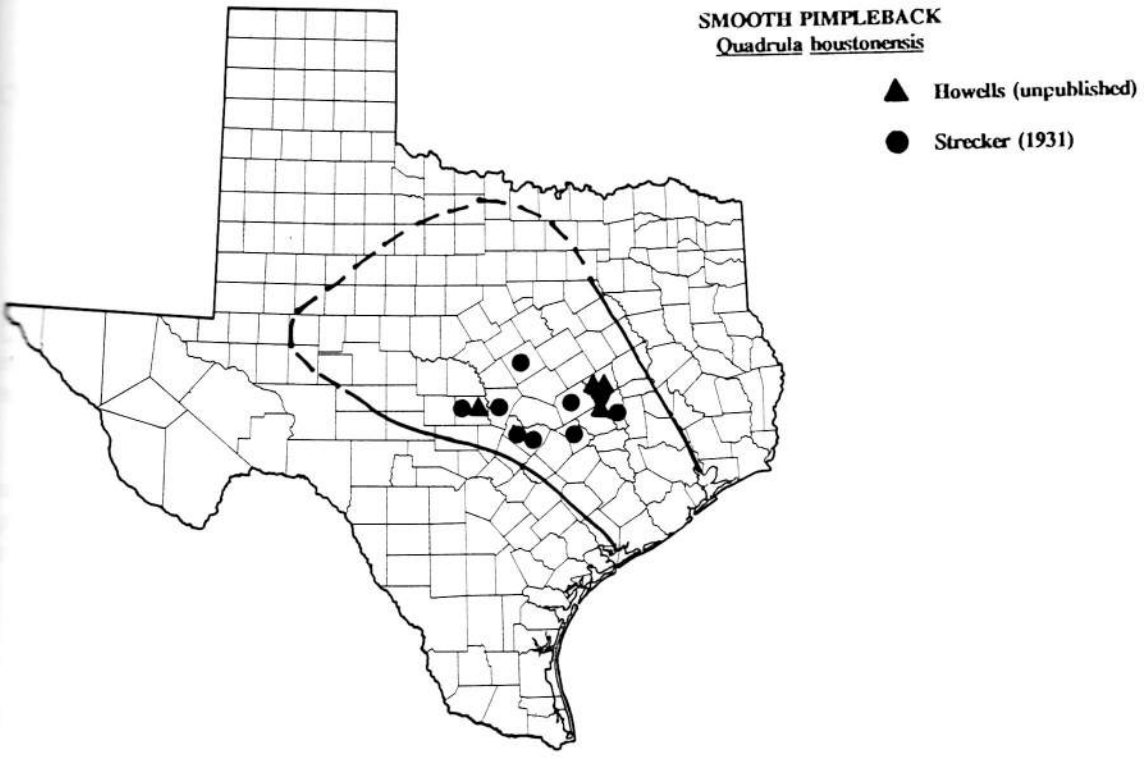
SPAWNING: No gravid females were found among specimens collected July through October [RGH].

GLOCHIDIA: Unreported.

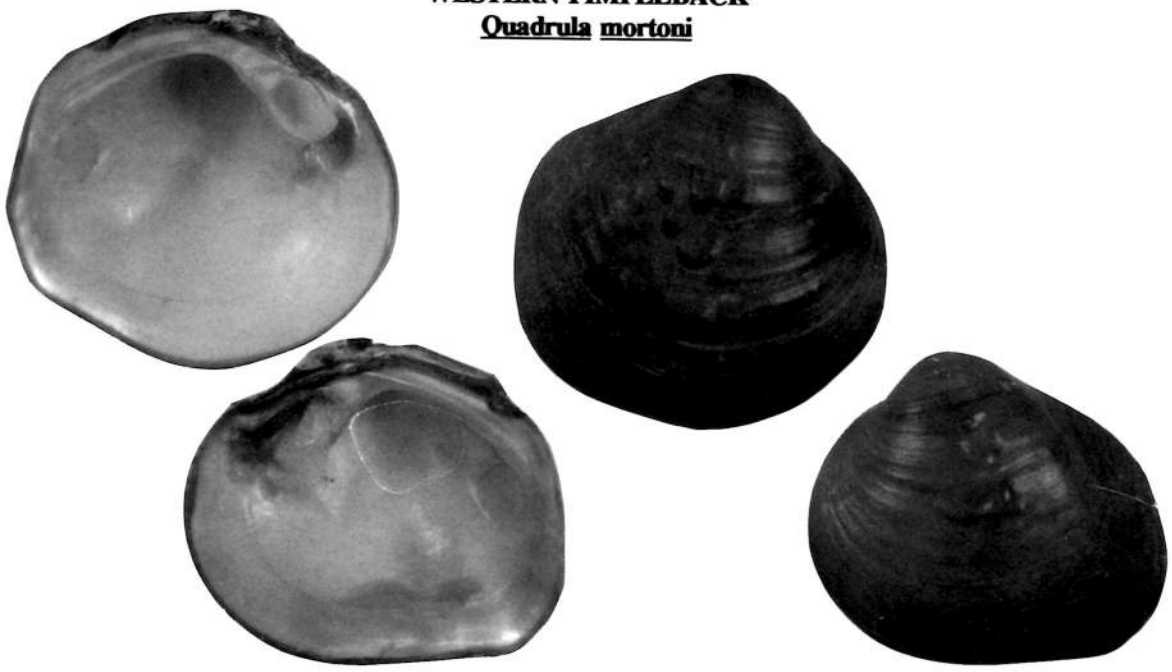
HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

COMMENTS: The American Fisheries Society considers this species threatened (Williams et al. 1993). The taxonomic status of this species is unclear; differences between smooth pimpleback and golden orb (Q. aurea) blur in some central and western waters and as do differences between it and western pimpleback (Q. mortoni) in more-eastern waters.



WESTERN PIMPLEBACK
Quadrula mortoni



Western pimpleback (Quadrula mortoni): Neches River, Jasper County, Texas, May 1993; both 52 mm shell length; TPWD.

OTHER COMMON NAMES: Mortons pimpleback.

SYNONYMY: (Simpson 1914; Strecker 1931).

Unio mortoni Conrad 1836
Unio sphaecius Lea 1868
Margarita turgidus Lea 1836
Unio turgidus Lea 1838
Margaron turgidus Lea 1852
Unio nodiferus Conrad 1841
Quadrula mortoni, Simpson 1900
Quadrula pustulosa mortoni Conrad 1836

Currently listed by the American Fisheries Society (Turgeon et al. 1988) as a subspecies of pimpleback (Q. pustulosa mortoni); its actual taxonomic status is probably best considered unresolved. Vidrine (1993) listed it at the specific level. Littleton's (1979) discussion of pimpleback (Q. pustulosa) from the Navasota River probably refers to this species [RWN].

DISTRIBUTION: Occurs in the San Jacinto, Trinity, Neches, and Sabine river drainage basins, with reports from the lower Colorado and Brazos rivers as well; also, reported by Simpson (1914) from Louisiana, Oklahoma, and western Tennessee; distribution presented by Vidrine (1993) indicates presence in eastern and southeastern Texas.

DESCRIPTION: (Simpson 1914; Strecker 1931; RGH).

Size: Reported to 67 mm shell length and 59 mm shell height (Littleton 1979), also to 60 x 52 mm (Simpson 1914); largest specimen taken in TPWD samples in 1992 was 58 x 54 mm [RGH].

Shell: Often very round but may be more elongate than some pimplebacks (Q. pustulosa); inflated; subsolid to solid in older specimens; rounded anterio-ventrally, rounded or sometimes straight or slightly concave ventrally just anterior to the posterior ridge, curved dorsally, often truncated posteriorly; beaks high, full, turned

forward, beak cavities moderately deep; posterior ridge well developed, but rounded, and often somewhat double ventrally; exteriorly often smooth except for concentric growth rings, but variable and sometimes with pustules or tear-shaped lunules.

Shell Teeth: Two left pseudocardinal teeth not widely separated; posterior tooth much smaller and deeply grooved, triangular; anterior tooth more massive, striated, subtriangular to nearly square, elevated well above hinge line; one right pseudocardinal tooth subtriangular to nearly square, striated, elevated slightly above hinge line, with a smaller, compressed anterior denticle; lateral teeth relatively short, ca. 40% shell length; slightly curved, right tooth reportedly slightly double in some specimens.

External Color: Dark umber brown to black; lighter on the beaks.

Internal Color: White; also described as having a purplish tint or as being purple; sometimes iridescent posteriorly.

Soft Tissues: Dirty white to pale tan.

HABITAT: This species occurs in both flowing streams and rivers, as well as lotic waters in reservoirs; collected from less than 1 m to over 3 m in depth; often on sand and mud [RGH].

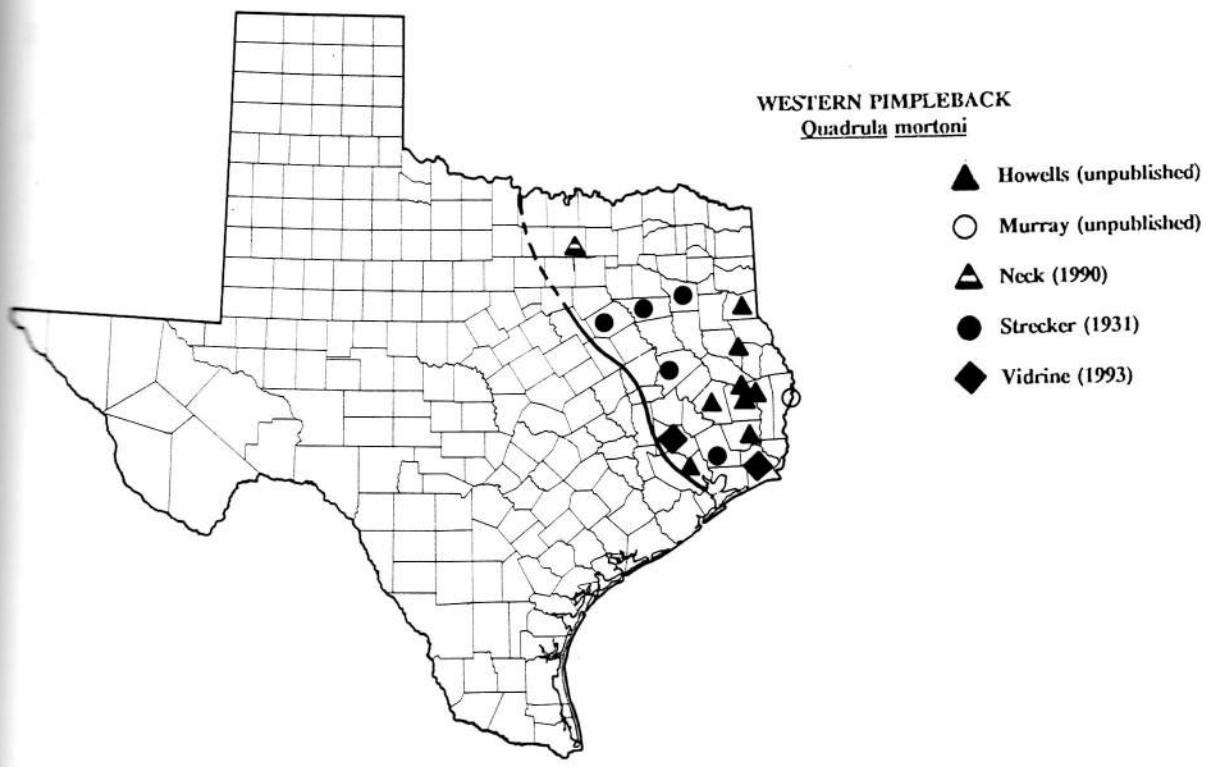
SPAWNING: Littleton (1979) reported gravid females in July and August, with the smallest mature female 40 mm shell length; he considered the species tachytictic.

GLOCHIDIA: Unreported.

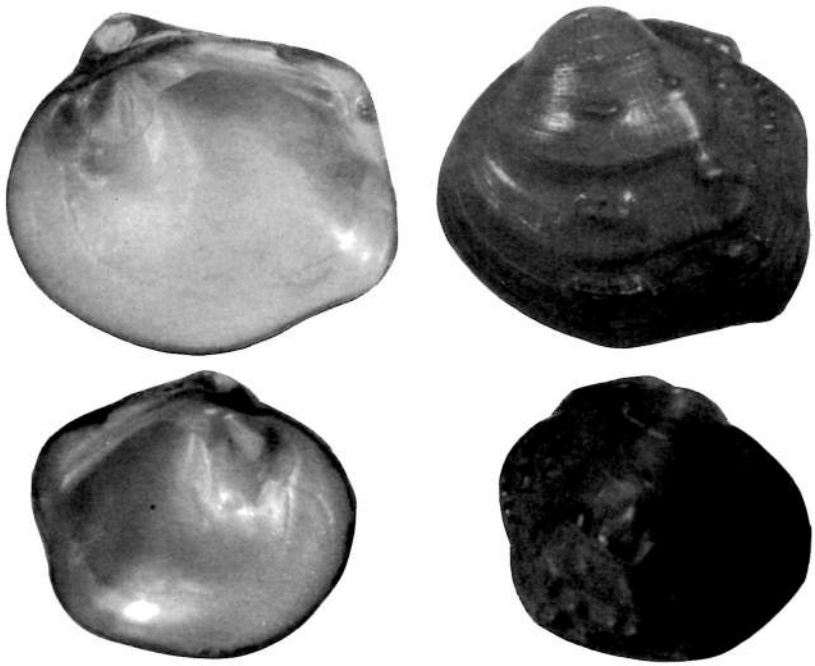
HOSTS: Unreported.

ECONOMIC IMPORTANCE: Larger specimens may be taken occasionally by musselers taking shell for the cultured pearl industry who may collectively include them under "pimplebacks"; however, most specimens are probably too small to provoke major interest.

COMMENTS: Although pimplebacks (pustulosa-types) have been regularly reported in Texas, most Texas populations may in fact prove to be mortoni-types. Sampling in the Neches River below B.A. Steinhagen Reservoir, Jasper County, Texas, [RGH] produced specimens apparently representing both species.



WARTYBACK
Quadrula nodulata



Wartyback (Quadrula nodulata): Top Neches River, Jasper County, Texas, May 1993; 57 mm shell length; TPWD. Bottom Sanders Creek, Lamar County, Texas; J.A.M. Bergman, O.M.C., Boerne, Texas.

OTHER COMMON NAMES: Pimpleback, winged pimpleback, twohorned pocketbook, winged orbshell, nodule shell.

SYNONYMY: (Strecker 1931; Murray and Leonard 1962; Starrett 1971; Oesch 1984, Vidrine 1993).
Obliquaria nodulata Rafinesque 1820
Obovaria nodulata Rafinesque 1820
Unio pustulatus Lea 1834
Unio nodulatus Say 1834
Unio pustulata, Scammon 1906
Quadrula nodulata (Rafinesque 1820)
Quadrula pustulata (Lea 1834)

Classification of some quadrulids is confused. Similarity of some forms to mapleleaf (Q. quadrula) and pimpleback (Q. pustulosa) makes some reports of wartyback questionable.

DISTRIBUTION: Reported by Strecker (1931) from the Sabine and Neches rivers, by Vidrine (1993) from the Neches River; specimens taken in 1993 from the Neches River below B.A. Steinhagen Reservoir, Jasper County, appear identical to photographs presented by Vidrine (1993).

DESCRIPTION: (Strecker 1931; Murray and Leonard 1962; Oesch 1984; Vidrine 1993; RGH).

Size: To at least 58 mm shell length in Texas [RGH], with other reports to 64 mm in Missouri (Oesch 1984), 57 mm in Kansas (Murray and Leonard 1962), and 76 mm in Arkansas (Harris and Gordon undated).

Shell: Nearly circular to subquadrate; moderately thick and solid anteriorly, thinner posteriorly; inflated to slightly inflated: gently rounded dorsally, rounded anteriorly and ventrally, slightly truncated to nearly straight

posteriorly (occasionally even slightly indented); beaks rise above the hinge line, narrow, high, incurved; beak cavities deep; posterior ridge rounded and prominent; posterior field sometimes almost wing-like; sulcus anterior to posterior ridge largely lacking; with two prominent rows of pustules running from the beak to the ventral margin, other smaller pustules may be present anterior or posterior to the two major rows, pustules typically present on the posterior field and often form ill-defined rows; concentric growth-rest lines relatively fine.

Shell Teeth: Left valve with two, large, triangular, grooved, rough pseudocardinal teeth; right valve with one heavy, triangular, finely-striated, grooved pseudocardinal tooth, often with a large denticle anteriorly and a smaller denticle posteriorly; lateral teeth relatively long, thick, lightly striated, and slightly curved to nearly straight.

External Color: Yellowish-brown, sometimes greenish-brown on the beaks; slightly darker in older individuals; reportedly sometimes weakly rayed; usually shiny.

Internal Color: White; slightly iridescent posteriorly.

Soft Tissues: Generally white in color, with foot and gills sometimes slightly tan or yellowish-brown.

HABITAT: Wartyback occurs on gravel and sand-gravel bottoms in medium to large rivers (Harris and Gordon undated) and has also been reported on mud and as commonly found at depths of 3 m or greater (Parmalee 1967). Specimens taken in the Neches River were found with mapleleafs (Q. quadrula and Q. apiculata), pimplebacks, and western pimplebacks (Q. mortoni) in swift water at depths of 6.1-7.6 m [RGH]

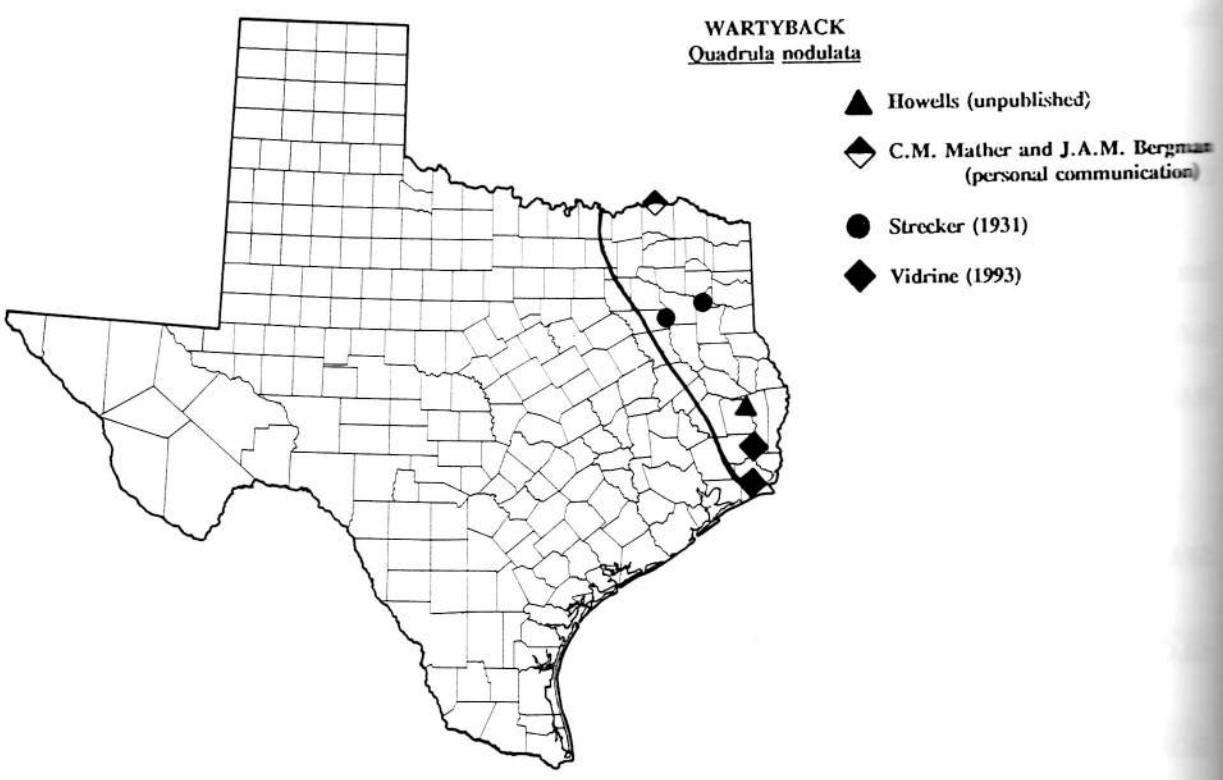
SPAWNING: It has been reported as a short-term, tachytictic breeder, spawning in June and July (Oesch 1984); specimens taken in the Neches River, Jasper County, in early May were not gravid [RGH].

GLOCHIDIA: Shell semi-elliptical in shape, without hooks or spines, large, 0.230 x 0.290 mm (Utterback 1915-16); nearly identical to those of pimpleback.

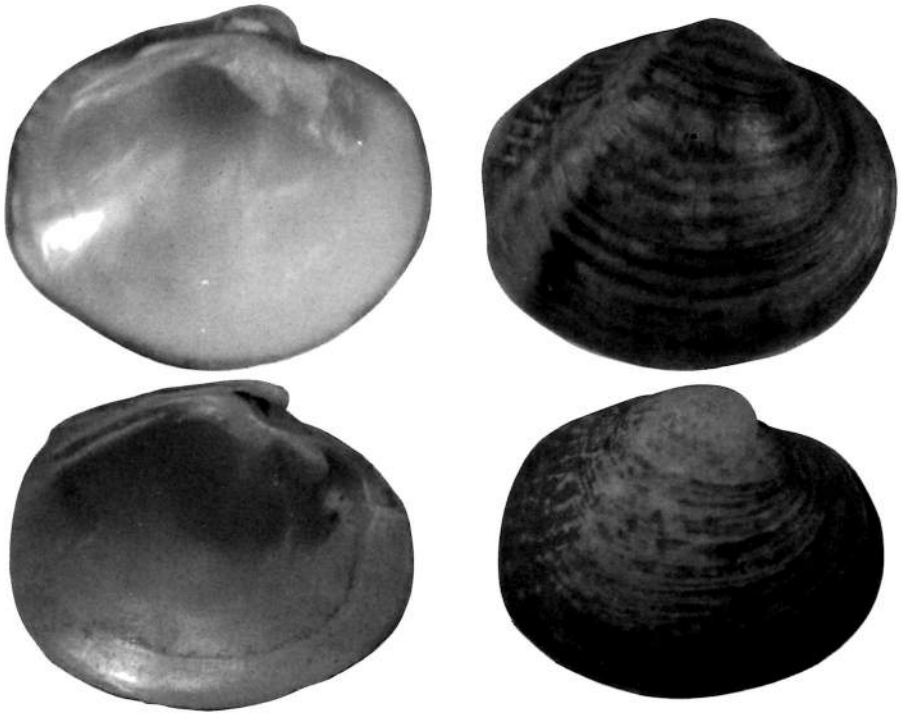
HOSTS: Channel catfish (Ictalurus punctatus), flathead catfish (Pylodictis olivaris) (Fuller 1978), white crappie (Pomoxis annularis) (Surber 1913), black crappie (P. nigromaculatus), largemouth bass (Micropterus salmoides), and bluegill (Lepomis macrochirus) (Fuller 1978).

ECONOMIC IMPORTANCE: Although usually too small to be of value, some larger individuals are probably taken for the cultured pearl industry, and others may be used to produced polished shell chips.

COMMENTS: Murray and Leonard (1962) indicated wartyback was sometimes confused with pimpleback, but could be distinguished by its more quadrate form, presence of two divergent rows of tubercles, and somewhat lighter epidermis. Vidrine (1993) differentiated wartyback from mapleleaf by the absence of a sulcus between the dorso-ventral rows of pustules (mapleleaf has a definite concave furrow or sulcus between these rows) and its tan or yellowish color (often greenish-brown, dark brown, or black in mapleleaf). The area between the rows of tubercles may slope gently from one row to the other in wartyback, but is not concave as in mapleleaf. Additionally, mapleleaf specimens taken in the Neches River along with wartybacks typically showed finer, but more continuous and well-defined ridges in the posterior field than did wartybacks, which had rounded or elongated pustules sometimes joined to form ridges which were often coarser and more separated.


WARTYBACK
Quadrula nodulata
Howells (unpublished)
C.M. Mather and J.A.M. Bergman (personal communication)
Strecker (1931)
Vidrine (1993)

TEXAS PIMPLEBACK
Quadrula petrina



Texas pimpleback (Quadrula petrina): Top Concho River, Concho County, Texas, June 1993; 68 mm shell length; TPWD. Bottom San Saba River, Menard County, Texas, August 1992; 34 mm; TPWD.

OTHER COMMON NAMES: Pimpleback.

SYNONYMY: (Simpson 1914; Strecker 1931).
Unio petrinus Gould 1855
Margaron petrinus Lea 1870
Unio bolli Call 1881
Quadrula petrina Gould, Simpson 1900

DISTRIBUTION: Occurs in the Guadalupe and Colorado river systems, including reports from the Llano, San Saba, and Pedernales rivers.

DESCRIPTION: (Simpson 1914; RGH).

Size: To 87 mm shell length and 75 mm shell height in Texas [RGH]; also reported to 70 mm in length and 53 mm in height (Simpson 1914).

Shell: Subelliptical, subrhomboidal, or subquadrate, slightly oblong, rounded; shell height to length ratio mean 79% (75.2-85.2%), less in elongate gravel-bar forms (65.5%); slightly inflated (often less so than other pimplebacks); moderately thick and solid; broadly rounded anteriorly, rounded ventrally, slightly rounded dorsally, truncated posteriorly; beaks above hinge line, high or not high, full, turned forward, beak cavities deep and compressed; posterior ridge widely rounded; externally often smooth except for fine concentric growth lines and the posterior slope, ornamentation often ill-defined when present, chevron or V-shaped marks or straight ridges present on the posterior slope.

Shell Teeth: Two or three left pseudocardinal teeth (or two teeth and a denticle), both elevated, triangular, very slightly to strongly roughened; a groove separates the teeth which is deep ventrally but shallow dorsally

(sometimes not below the shell edge); two right pseudocardinal teeth; anterior tooth small, triangular, compressed, not elevated above hinge line; posterior tooth triangular to subrectangular, elevated, flattened anterio-dorsally, striated lateral teeth two left and one right, slightly curved to nearly straight, slightly striated, not highly elevated, often relatively square posteriorly, ca. 35% shell length.

External Color: Tan to brown; some yellow-tan or dirty straw-colored with irregular bands or broken splotches of green; yellow and bright green markings sometimes very distinctive; somewhat glossy.

Internal Color: White, slightly pearly to very iridescent posteriorly.

Soft Tissues: White to off-white, gills yellowish-tan.

HABITAT: It has been found in mud and gravel, at slow flow rates, 0.5-1.0 m in depth in the Concho River, Concho County, Texas, and shells have found on sand and gravel in shallow, flowing waters in the San Saba River, Menard County, Texas [RGH]. Concho River specimens occurred in dense beds of Asian clams (Corbicula spp.) where numbers of this exotic species exceeded 2,200/m^2 [RGH].

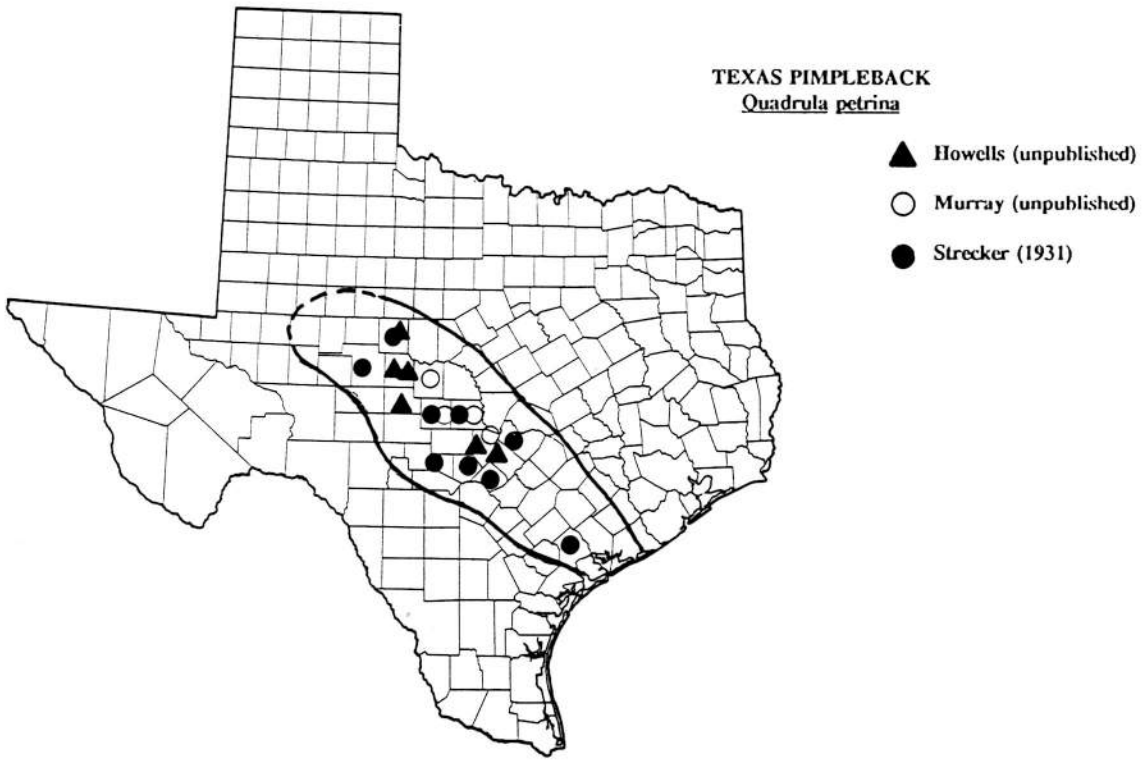
SPAWNING: Females with developing eggs and glochidia were taken in mid-June in the Concho River, Concho County, Texas [RGH]. The smallest mature female examined was 45 mm shell length [RGH].

GLOCHIDIA: Shells elliptical, hookless, medium-sized, 0.205-0.246 mm shell length, 0.311 mm shell height, and 0.136 mm along the hinge line [RGH].

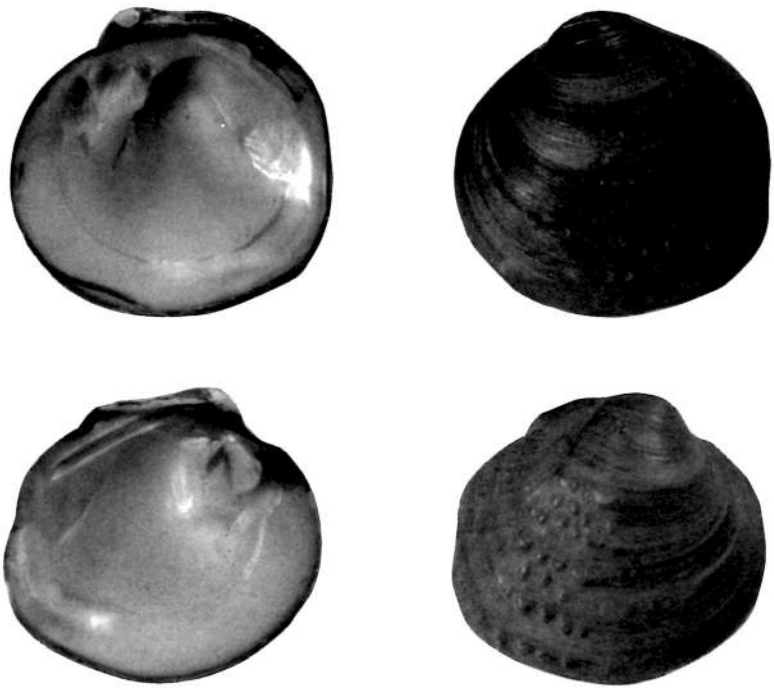
HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

COMMENTS: The American Fisheries Society considers this species threatened (Williams et al. 1993).



PIMPLEBACK
Quadrula pustulosa



Pimpleback (Quadrula pustulosa): Q. pustulosa-type pimpleback from Texas, Sanders Creek, Lamar County, Texas, August 1993; ca. 43 mm shell length; J.A.M. Bergman, Boerne, Texas.

OTHER COMMON NAMES: White pimpleback, pimple-backed mussel, wartyback.

SYNONYMY: (Strecker 1931; Murray and Leonard 1962; Oesch 1984).

Unio pustulosus Lea 1831
Unio nodulosus Say 1834
Unio dorfeuillianus Lea 1838, Singley 1893
Unio dorfeuillianus, Call 1885
Unio kienerianus Lea 1852, Singley 1893
Quadrula pustulosa (Lea), Baker 1898

Because of the extreme variability in this species, Valentine and Stansbery (1971) termed it "one of the most bewildering species." True Q. pustulosa may not occur in Texas; however, a form from southern waters (Q. pustulosa var. cf. nodifera) with only a few small pustules or linear nodules may have "pustulosa" affinities [RWN].

DISTRIBUTION: Reported from the Brazos River drainage into systems to the north and east (some reports likely refer to mortoni- or houstonensis-type pimplebacks); actual pustulosa var. cf. nodifera seems to be restricted to extreme eastern Texas. Some specimens collected in the Neches River, Jasper County, Texas, by TPWD in 1993 [RGH] appear to be this type [RWN]. Specimens taken in Sanders Creek, Lamar County, Texas, by J.A.M. Bergmann and C.M Mather in 1993 appear to be this species.

DESCRIPTION: (Coker 1919; Murray and Leonard 1962; Oesch 1984; Fuller 1985).

Size: To at least 65 mm shell length in Texas [RGH]; typical pustulosa forms also reported to 78 mm in Missouri (Oesch 1984), 89 mm in Kansas (Murray and Leonard 1962), 86 mm in Tennessee [RGH], and 102 mm in the northcentral states (Cummings and Mayer 1992).

Shell: Quadrate, subrhomboidal, to nearly circular; moderately thick to thick, evenly thick or thinner posterio-ventrally; moderately inflated; rounded dorsally, anteriorly, and ventrally, rounded to slightly truncated posteriorly; beaks high and well above hinge line, beak cavities deep; posterior ridge prominent, lacks a sulcus associated with the posterior ridge; externally highly variable ranging from entirely smooth or bearing large, irregular pustules, such pustules may be well developed, large, and elongated or misshapen, or may appear as little more than ill-defined wrinkles, in no particular pattern; completely smooth forms are considered rare in some areas of the range.

Shell Teeth: Two left pseudocardinal teeth, large, erect, striated, and rough; single right pseudocardinal tooth, large, grooved, triangular, often with a small denticle on each side; lateral teeth short and slightly curved.

External Color: Yellow-brown, yellow-green, or brown, black in older shells; green coloration sometimes associated with the beak; growth-rest periods may show as alternating bands of color; usually rayless, occasionally reported as having green rays.

Internal Color: White, sometimes stained with brown; iridescent posteriorly.

Soft Tissues: Off-white.

HABITAT: Pimpleback is reported from small streams to larger rivers, and associated with nearly every bottom type except deep shifting sands (Oesch 1984). It is found from 0.5- to 1.9-m depths (Murray and Leonard 1962), to depths of 3.7 m (Buchanan 1980) and in standing water to flow rates of 51.8 cm/second (Buchanan 1980).

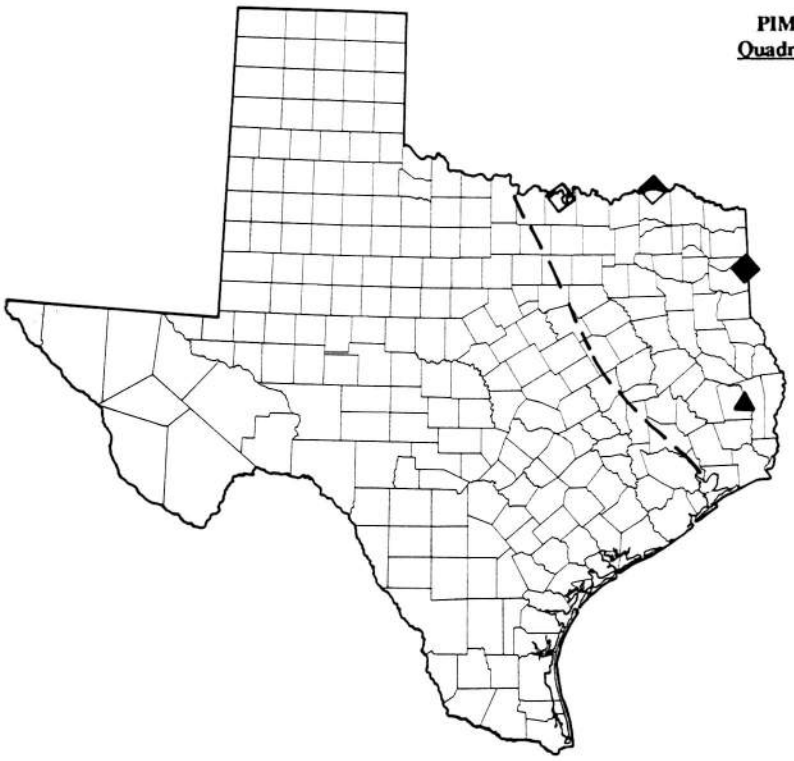
SPAWNING: It has been considered tachytictic with reported breeding from June through August (Howard 1914a).

GLOCHIDIA: Shells large, 0.230 x 0.300 mm, semielliptical, spineless, hinge lines short and curved (Utterback 1915-16); glochidia produced in conglutinate masses (Oesch 1984).

HOSTS: Shovelnose sturgeon (Scaphirhynchus platorynchus), black bullhead (Ameiurus melas), brown bullhead (A. nebulosus), channel catfish (Ictalurus punctatus), flathead catfish (Pylodictis olivaris), and white crappie (Pomoxis annularis) (Fuller 1978).

ECONOMIC IMPORTANCE: Pimpleback was previously harvested by the shell-button trade and is occasionally harvested at present for shell used by the cultured pearl industry. It is often too small to be of value.

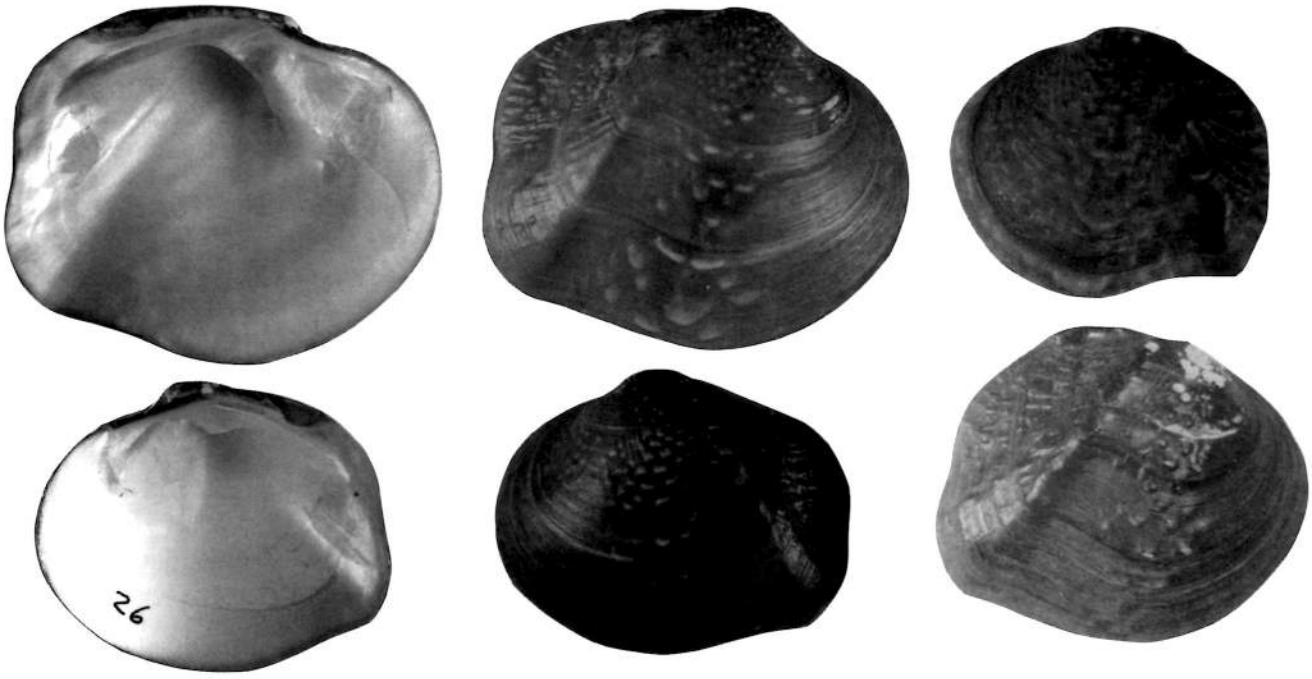
COMMENTS: Pimpleback is often confused with wartyback (Q. nodulata) and threehorn wartyback (Obliquaria reflexa), both of which have a sinus above the posterior ridge (Murray and Leonard 1962). Primary nodules on both species generally occur in both species in well-defined dorsal to ventral rows rather than randomly as in pimplebacks.



PIMPLEBACK
Quadrula pustulosa

- Howells (unpublished)
- C.M. Mather and J.A.M. Bergmann (personal communication)
- Vidrine (1993)
- White and White (1977)

MAPLELEAF
Quadrula quadrula



Mapleleaf (Quadrula quadrula): Top left and center 82 mm shell length Lake Arrowhead, Clay County, Texas, July 1994; 82 mm shell length; TPWD. Bottom left and center Lake Wichita, Archer County, Texas, July 1994; 68 mm; TPWD. Right Pine Creek, Lamar County, Texas, August 1993; top 55 mm, bottom 93 mm; TPWD

OTHER COMMON NAMES: Common mapleleaf, stranger.

SYNONYMY: (Murray and Leonard 1962; Starrett 1971; Valentine and Stansbery 1971; Oesch 1984).

Obliquaria quadrula Rafinesque 1820
Unio lachrymosus Lea 1828
Unio asperrimus Lea 1831
Unio quadrulus, Say 1834
Unio quadrulus Rafinesque = U. asperrimus Say, Ferussac 1835
Quadrula lachrymosa, Baker 1898
Quadrula asperrima Lea, Kelly 1899
Quadrula quadrula Rafinesque = Q. lachrymosus (Lea), Vannatta 1915
Quadrula quadrula Rafinesque, Simpson 1914, Utterback 1916.
Quadrula forsheyi, of Isley 1925
Quadrula fragosa, of Isley 1925
Tritogonia nobilis, of Isley 1925

DISTRIBUTION: Reported from the San Jacinto River into drainages to the north and east, but may be confined to the Red River drainage in Texas.

DESCRIPTION: (Murray and Leonard 1962; Oesch 1984).

Size: To at least 110 mm shell length in Texas [RGH]; also reported as 102-127 mm (Coker et al. 1921), 133 mm in Missouri (Oesch 1984), and 140 mm in Kansas (Murray and Leonard 1962).

Shell: Quadrate; moderately inflated; thick, especially near the hinge; solid; dorsal margin straight or slightly curved, ventrally curved or straight but concave where the median ridge meets the margin, rounded anteriorly, more or less bluntly truncated posteriorly; beaks raised above the hinge line, beak cavities deep; posterior ridge prominent, with a relatively deep sulcus anteriorly, and often a median ridge ahead of the sulcus; growth lines often apparent externally; pustules often elongate or drop-shaped; pustules occur in two or three rows with one row on the posterior ridge and a second row anterior to the sulcus, and often a third row on the posterior slope; beaks may have pustules in rows as well. Texas specimens sometimes fail to show the two, dorsal to ventral rows of pustules typical of the species; some individuals and populations have limited ornamentation and others may be nearly apustulose [RGH].

Shell Teeth: Two left pseudocardinal teeth large, erect, rough, grooved, and triangular; right pseudocardinal tooth usually single, large, erect, and triangular, only rarely with an anterior or posterior denticle; lateral teeth straight and ca. 36% shell length (reported as "long" by some authors).

External Color: Yellow-brown, becoming chestnut-brown with age, older individuals may be nearly black.

Internal Color: White; iridescent posteriorly.

Soft Tissues: Off-white to tan or flesh-colored; gravid marsupia darker brown.

HABITAT: Mapleleaf prefers rivers and larger streams, but adapts to favorable conditions in lakes with clear to turbid waters, in small to medium gravel and rocks, with or without associated mud (Oesch 1984). It is also reported from mud, rock, gravel, and sand (but not deep, shifting sand), and in shallow or deep waters (Murray and Leonard 1962). It was described by Stansbery (1965) as characteristic of oxygen-rich riffles and runs. Mapleleaf has been reportedly called "stranger" because of random occurrences among other mussels (Coker 1919). Williams and Schuster (1989) found this species in the Ohio River at depths greater than 9.1 m.

SPAWNING: Mapleleaf has been considered tachytictic, with spawning May to August (Baker 1928); specimens taken in the Pine Creek (Lamar County), Lake Wichita (Wichita County), and Lake Arrowhead (Clay County) in August were not gravid [RGH].

GLOCHIDIA: Shell reported as purse shape, 0.078 mm shell length and 0.085 mm shell height (Howard 1914a); described by Surber (Oesch 1984) and Howard (1914a) as the smallest of any Quadrula (however, note glochidia of southern mapleleaf, Q. apiculata, had not been described at that time).

HOSTS: Flathead catfish (Pylodictis olivaris) (Howard and Anson 1922); Coker (1919) reported use of other catfishes as well.

ECONOMIC IMPORTANCE: Mapleleaf was used previously by the shell-button industry. It is now taken for shell by the cultured pearl industry. Mapleleaf can produce gem-quality pearls, but apparently does so only rarely, and is not generally sought in Texas as a pearl mussel.

COMMENTS: Neck (1984) listed mapleleaf status as uncertain in Texas; locally rather uncommon [RWN]. The more abundant southern mapleleaf may lack the deep sulcus, rarely has ornamentation in dorsal to ventral rows, often has ornamentation in the sulcus, and usually displays only small, conical pimples (rather than larger drop-shaped pustules).

NOTE: Just before going to press, it became apparent (based on electrophoretic evidence) the mapleleaf typically called Q. quadrula from southeastern Texas was actually an additional species distinct from both Q. quadrula and Q. apiculata. See inserted species description for Gulf mapleleaf, Q. nobilis, on pages 198 through 200.

Shell Teeth: Pseudocardinal teeth double in both valves, heavy, nearly triangular, with the right anterior pseudocardinal tooth relatively small; lateral teeth double in the left valve and single in the right, relatively short, nearly straight, with a club-shaped expansion posteriorly.

External Color: Tawny-brown, beaks and posterior slope orange-yellow; often rayed with yellow-olive or olive-green markings with a single, olive-green ray on the posterior slope.

Internal Color: White; iridescent posteriorly.

Soft Tissues: Unreported.

HABITAT: Wurtz (1950) reported the species from the Guadalupe River in water about 61 cm deep on substrates of cobble and mud, with water lilies present.

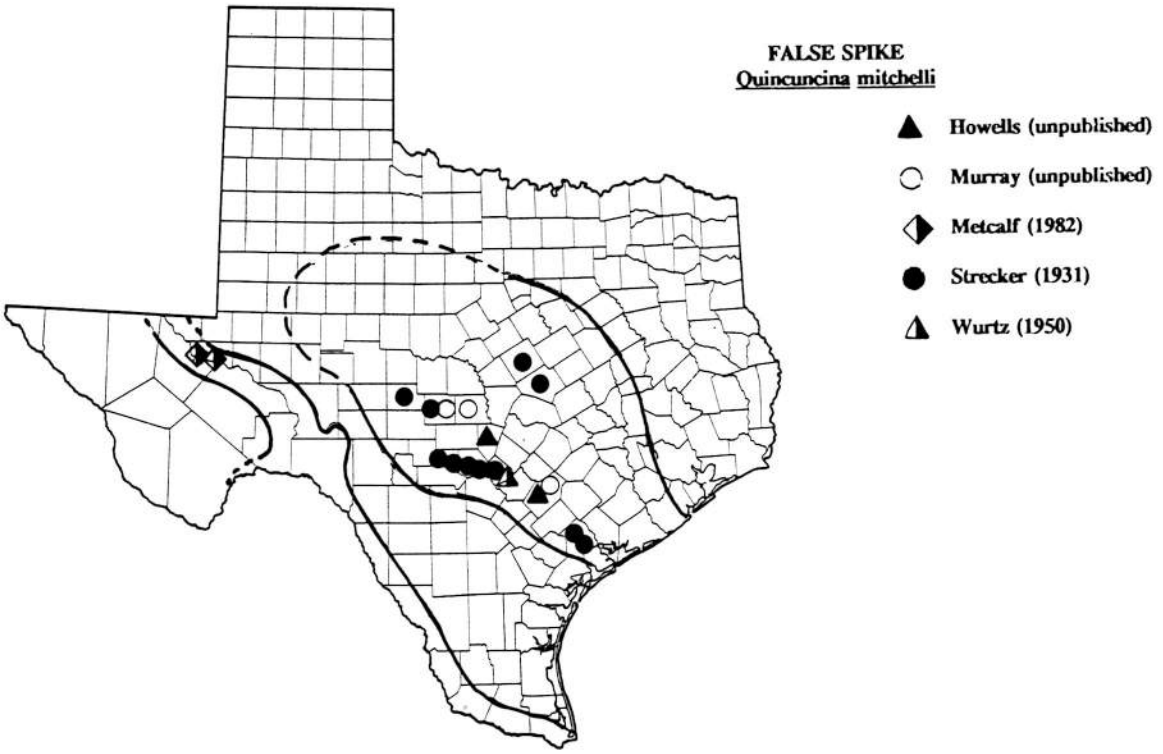
SPAWNING: Unreported.

GLOCHIDIA: Unreported.

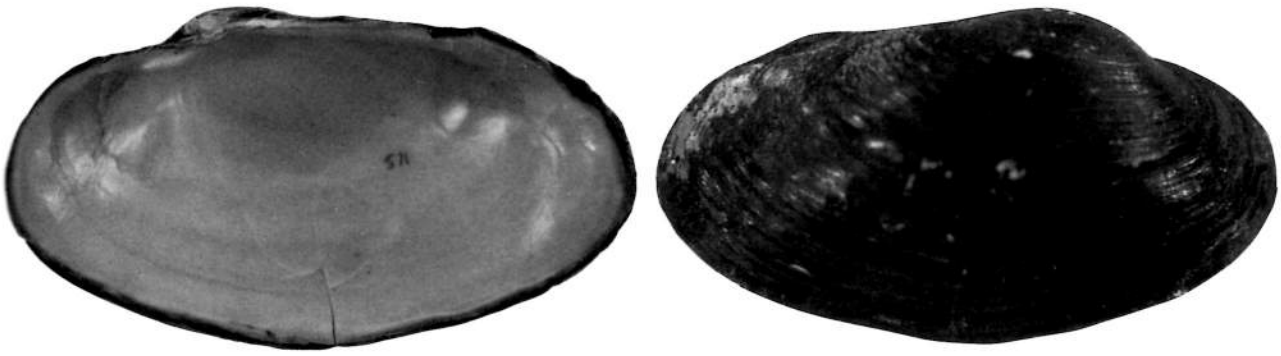
HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

COMMENTS: Stansbery (1971) listed this species as rare and endangered. Metcalf (1982) presented photographs of fossil Rio Grande material, and Wurtz (1950) provided photographs of a Guadalupe River specimen. The American Fisheries Society considers this species threatened (Williams et al. 1993).



SQUAWFOOT
Strophitus undulatus



Squawfoot (Strophitus undulatus): San Marcos River, Gonzales County, Texas, September 1965; 92 mm shell length; TUC.

OTHER COMMON NAMES: Strange floater, sloughfoot, creeper.

SYNONYMY: (Strecker 1931; Murray and Leonard 1962; Oesch 1984).
Anodonta undulata Say 1817 (also as 1816)
Alasmodonta edentula Say 1820 (also as 1829)
Anodon rugosus Swainson 1822
Anodonta arkansensis Lea 1852
Anodonta edentula, Call 1886
Strophitus edentulus (Say), Simpson 1900
Strophitus rugosus, Dall 1905

DISTRIBUTION: Occurs from the Guadalupe River drainage into systems to the north and east.

DESCRIPTION: (Murray and Leonard 1962; Fuller 1985; Oesch 1984).

Size: To at least 92 mm shell length in Texas [RGH]; also reported to 107 mm in Missouri (Oesch 1984) and 108 mm in Kansas (Murray and Leonard 1962).

Shell: Oblong, oval, subelliptical, or suboval; thin and fragile when small, but thicker and more stout with age; more or less inflated; dorsal and ventral margins rounded, broadly rounded anteriorly, more sharply rounded posteriorly, hinge line may be undulate; beaks narrow and only slightly raised above the hinge line, beak cavities shallow; posterior ridge rounded, ill-defined, indistinct; externally relatively smooth, often with several well-defined concentric rings.

Shell Teeth: One right and one or two left pseudocardinal teeth reduced to minor thickenings or tubercles at the hinge line; lateral teeth absent.

External Color: Yellow-brown to greenish-brown, brown to black with age; wavy green rays sometimes present posteriorly, but older specimens often rayless.

Internal Color: Bluish-white, sometimes creamy, may be bordered with pink; iridescent posteriorly.

Soft Tissues: Foot, palps, and adductor muscles orange, but variable.

HABITAT: This species has been reported from small to large streams; it prefers gravel or gravel and mud in flowing water (Oesch 1984). Baker (1928) indicated occurrence in large to medium rivers on mud and sand in fairly deep water; Murray and Leonard (1962) listed it occasionally from gravel and cobble. Buchanan (1980) also reported it from silt, at flow rates from still to 61 cm/second, and at depths from 2.5 to 91.4 cm. Metcalf (1982) noted squawfoot seemed especially sensitive to drought conditions.

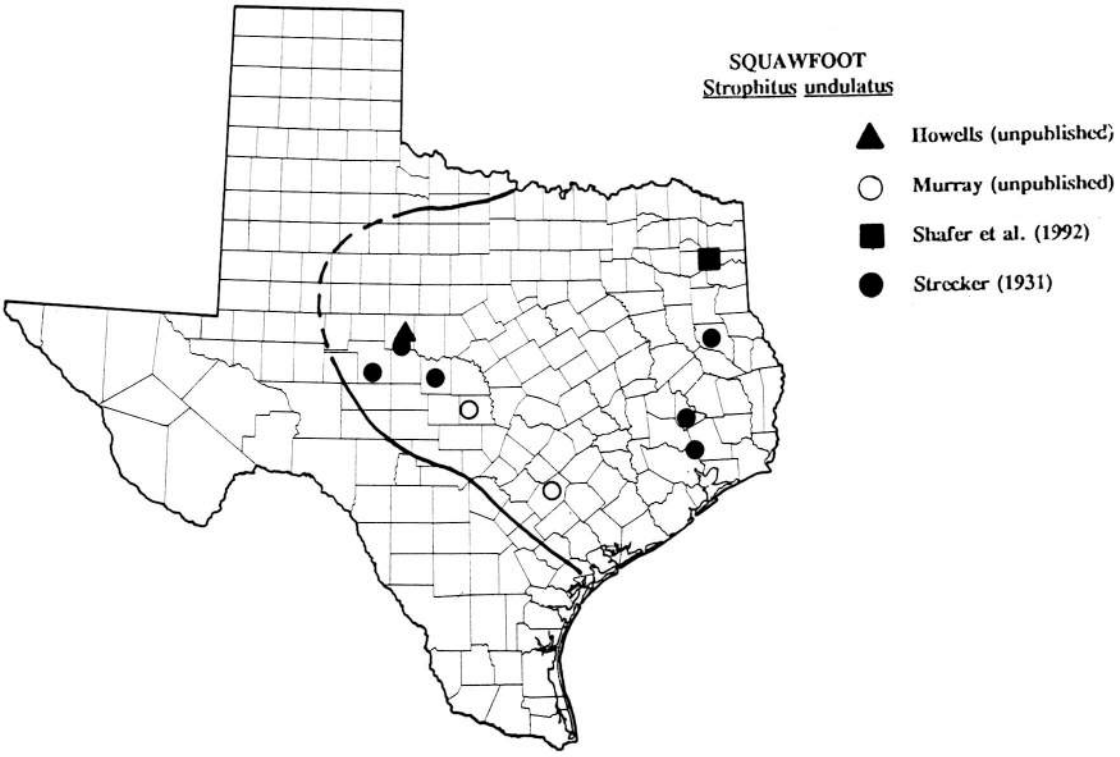
SPAWNING: Squawfoot has been considered bradytictic with gravid females reported from July to April and May (Baker 1928). Squawfoot may be able to complete its life cycle without a fish host (Lefevre and Curtis 1911).

GLOCHIDIA: Shell large, spade-shaped, 0.350 x 0.285 mm, spined, hinge line straight (Utterback 1915-16). Hoggarth (1988) described glochidia as depressed, pear-shaped, asymmetrical, 0.360-0.369 mm shell length, 0.353-0.355 mm in shell height, and 0.270-0.281 mm dorsally along the hinge line, with styliform hooks carrying about 30 microstylets and micropoints.

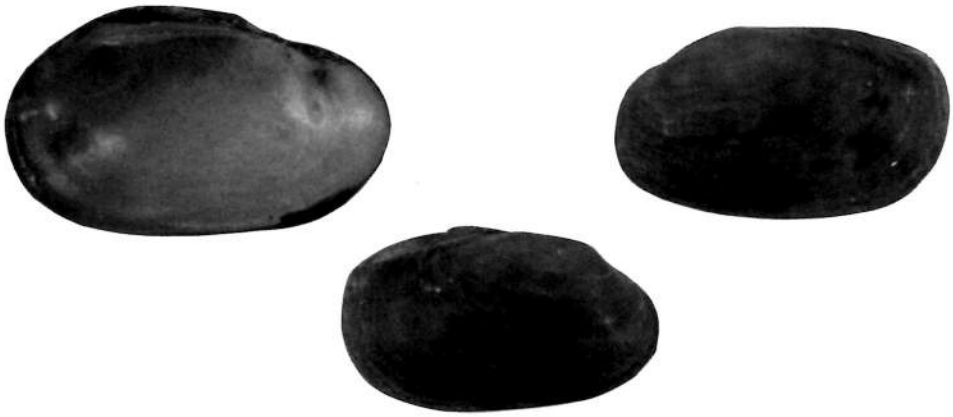
HOSTS: Largemouth bass (Micropterus salmoides) and creek chub (Semotilus atromaculatus) experimentally (Baker 1928); Rio Grande killifish (Fundulus zebrinus) and green sunfish (Lepomis cyanellus) (Fuller 1978).

ECONOMIC IMPORTANCE: None.

COMMENTS: Strecker (1931) listed southern creek mussel (Strophitus subvexus) as rare in Texas, but subsequent authors generally fail to recognize this species as present. However, Vidrine (1993) reported southern creek mussel from the Sabine River drainage of Louisiana; apparent squawfoot specimens from eastern Texas should be examined with this related species in mind.



LILLIPUT
Toxolasma parvus



Lilliput (Toxolasma parvus): Pat Mayse Reservoir, Lamar County, Texas, August 1993; 23 mm shell length; TPWD.

OTHER COMMON NAMES: Lilliput shell, common lilliput.

SYNONYMY: (Murray and Leonard 1962; Valentine and Stansbery 1971; Oesch 1984).
Unio parvus Barnes 1823
Unio haleianus Lea 1842
Lampsilis parvus, Simpson 1900
Eyrynia parva, Ortmann 1912
Carunculina parva, Utterback 1916
Lampsilis parva, Isley 1925
Lampsilis carunculus, Isley 1925

DISTRIBUTION: Reported from the Rio Grande and Red rivers, and several central Texas localities [RWN]; also, reported from the Nueces, Frio, Aransas, Guadalupe, San Saba rivers and San Miguel Creek, McMullen County [HDM].

DESCRIPTION: (Murray and Leonard 1962; Oesch 1984; Fuller 1985; Cummings and Mayer 1992).

Size: Reported as 34 mm shell length in Missouri (Oesch 1984), 28.6 mm in Kansas (Murray and Leonard 1962), and 40 x 24 mm in Indiana and 30 x 17 mm in Oklahoma (Valentine and Stansbery 1971).

Shell: Small, subelliptical to suboval to cylindrical; stout, thick, solid; inflated, females display a marsupial swelling posteriorly; dorsal margin straight, ventral margin nearly straight, rounded anteriorly, posteriorly truncated above and broadly rounded below in females, more pointed posteriorly in males; beaks broad, low, flattened, extending above the hinge line, beak cavities shallow; posterior ridge broadly rounded, low, and obscure to completely absent; externally smooth and silky except for fine concentric growth lines; described as not easily eroded, sometimes described as having a cloth-like texture.

Shell Teeth: Two left pseudocardinal teeth, erect, divergent, compressed, rough, triangular; single right pseudocardinal tooth, erect, grooved, triangular, with a small lamellar denticle anteriorly; lateral teeth moderately long, slightly curved, thin, roughened; a short shelf-like tooth may be present ventral to the right lateral tooth.

External Color: Light brown, green-tinted posteriorly, dark brown to black in older specimens; rayless; reported as lustrous externally, with a silky sheen.

Internal Color: Bluish-white, occasionally blue or purple, may show pinkish-yellow tints near the beak cavity; iridescent.

Soft Tissues: Pale white, but appears as pale brown due to presence of a large, pigmented liver. Female mantles are morphologically distinctive with a caruncle supported on a peduncle (a finger-like projection from the mantle flap present on both sides; see discussion under Texas lilliput T. texasensis).

HABITAT: Lilliput usually occurs in quiet waters; it often thrives in lakes; it may be found on mud or mud and sand (Oesch 1984). Buchanan (1980) reported it on silt and sand at water depths of 0.25-1.07 m. Murray and Leonard (1962) reported densities of 100 individuals within a radius of only "a few feet".

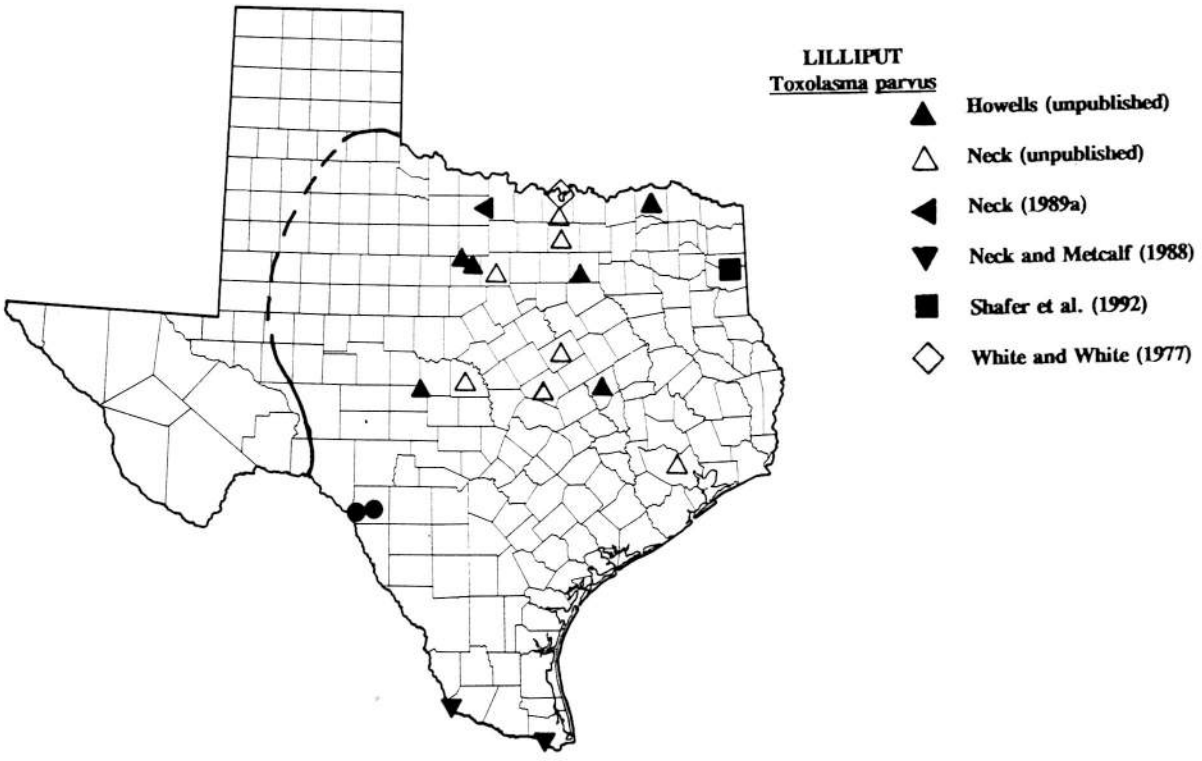
SPAWNING: Lilliput is probably bradytictic (Oesch 1984). Baker (1928) reported eggs present in August, and glochidia in May, June, and July. Sometimes hermaphroditic, but usually dioecious and sexually dimorphic (van der Schalie 1966).

GLOCHIDIA: Unreported.

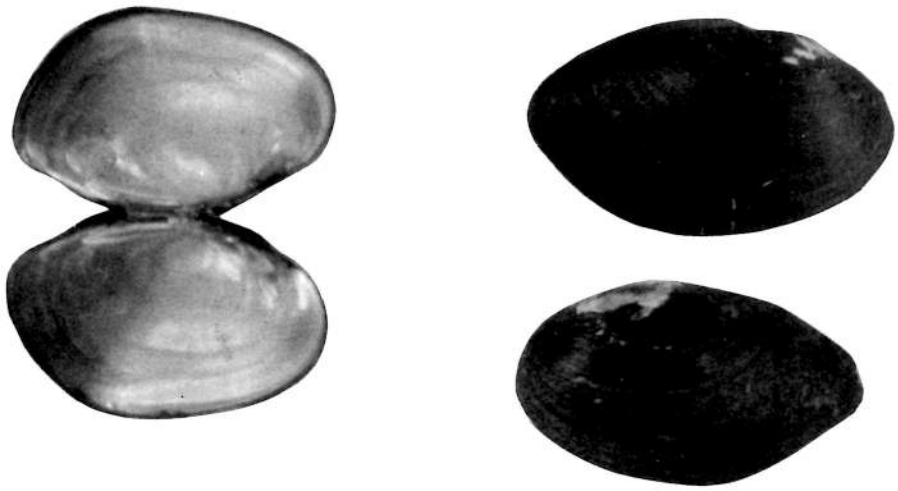
HOSTS: Warmouth (Lepomis gulosus), green sunfish (L. cyanellus), bluegill (L. macrochirus), orangespotted sunfish (L. humilis), and white crappie (Pomoxis annularis) (Mermillirod 1973).

ECONOMIC IMPORTANCE: None.

COMMENTS: Murray and Leonard (1962) discussed confusion with small pond mussels (Ligumia subrostrata); pond mussel is usually larger, is less rounded posteriorly, is less frequently dark black, and has inverted V's on beak sculpturing (half-circled ridges in lilliput). Fuller (1985) noted lilliput was often confused with young of other species.



TEXAS LILLIPUT
Toxolasma texasensis



Texas lilliput (Toxolasma texasensis): Giddings State School Lake, Lee County, Texas, June 1993; left 40 mm shell length, right 44 mm; TPWD.

OTHER COMMON NAMES: None.

SYNONYMY: (Strecker 1931; Valentine and Stansbery 1971).

Unio texasensis Lea 1857
Unio parvus Barnes 1823
Carunculina parva texasensis Lea, Strecker 1931
Toxolasma Rafinesque 1831
Toxolasma texasensis, Valentine and Stansbery 1971

Strecker (1931) also listed Unio bairdianus Lea 1857, U. bealii Lea 1862, and U. haleianus Lea 1842 as synonyms; whether these are actually synonyms or not is unclear. Western lilliput (T. mearnsi) from Texas is tentatively being considered a synonym of Texas lilliput here; preliminary electrophoretic analysis has thus far failed to distinguish texasensis- and mearnsi-forms [RGH].

DISTRIBUTION: All major drainages.

DESCRIPTION: (Valentine and Stansbery 1971; Neck 1986a; Cummings and Mayer 1992; RGH).

Size: Reported to 62 mm shell length and 34 mm shell height from the Trinity River, Texas (Valentine and Stansbery 1971), and 60 mm in length (presumably female) and 56 mm in length (presumably male) from Medina Lake, Medina and Bandera counties, Texas (Neck 1989b); most are probably 46 mm in length or less [RGH]. A report of lilliput (T. parvus) from the Navasota River, Texas, 75 mm in length (Littleton 1979) is Texas lilliput [RWN].

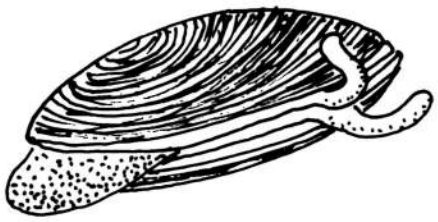
Shell: Small; elliptical, somewhat elongate in some males; inflated; thin to moderately thick; relatively solid; curved dorsally and anteriorly, ventrally broadly curved in males to nearly straight in some females, posteriorly round-pointed centrally in males and obliquely truncated in females (sexually dimorphic); beaks low and flattened, only slightly above hinge line, beak cavities shallow; posterior ridge slopes gradually to the shell margin; externally smooth except for concentric growth rings.

Shell Teeth: Two left pseudocardinal teeth erect, triangular, anterior tooth rough, serrate, posterior tooth decidedly more compressed; single right pseudocardinal tooth, subtriangular, round-pointed, with a compressed, leaf-like lamellar anterior denticle; lateral teeth curved or straight, thin, ca. 44% shell length.

External Color: Silky-brown, deep chestnut brown to nearly black.

Internal Color: Usually white with ocher highlights; also reported as orange, straw-colored, yellow, salmon, and pale blue; some individuals with a pinkish-bronze tints; iridescent.

Soft Tissues: Foot, mantle, and gills white; females with caruncles (finger-like extensions of the mantle) usually white, red in a single specimen from Lee County, Texas; caruncles can be extended to about 20% shell length [RGH]. Only the outer gills are used to incubate eggs and glochidia [RGH].



Female Texas lilliput extending and wiggling caruncles

HABITAT: Texas lilliput is typically found in still waters (Neck 1982b); Neck (1986a) reported this species from feeder creeks, protected or ponded waters on mud or sand. Shells were abundant at an oxbow pond adjacent to the San Marcos River at Palmetto State Park in Gonzales County, Texas, where depths were usually less than 1-2 m over a mud bottom; specimens were generally absent in the adjacent riverine areas where currents were swift and substrates were gravel, cobble, and deep, shifting sand [RGH]. Cummings and Mayer (1992) described it from small to medium streams and sloughs in mud and sand under slow-flow conditions. Some captives are extremely active, even on hard-bottomed laboratory tanks [RGH].

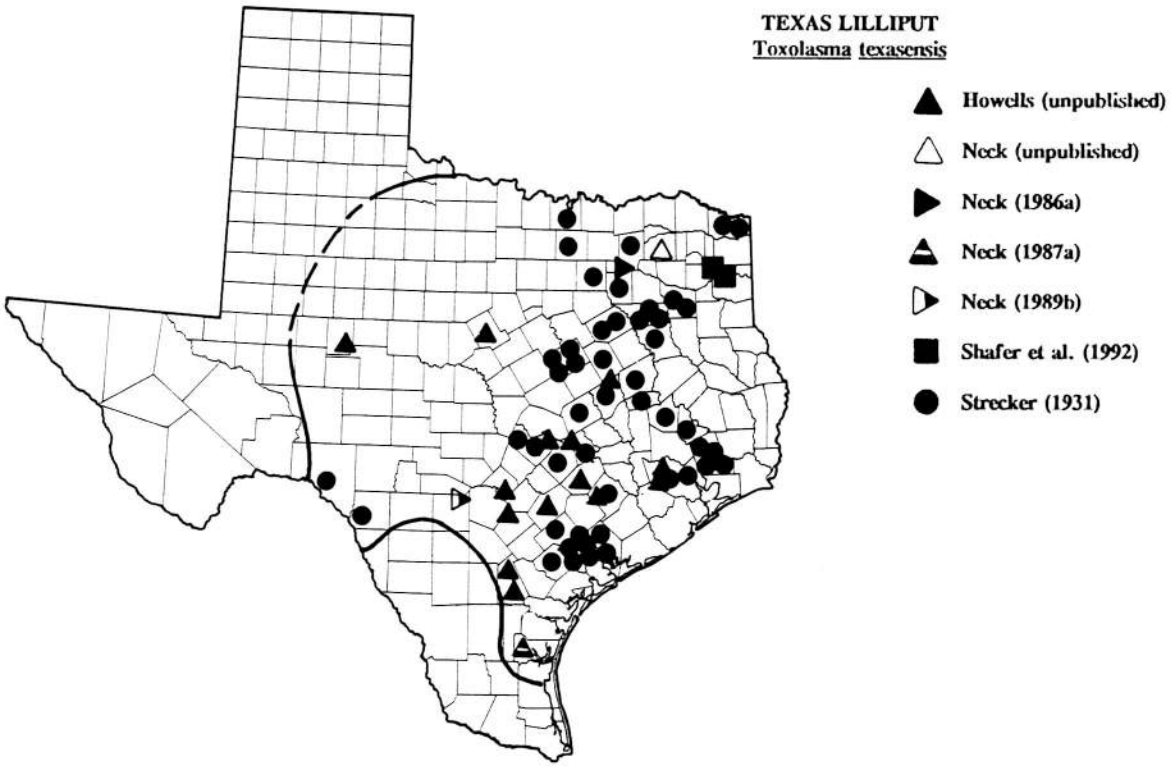
SPAWNING: It was reported by Read and Oliver (1953) as apparently a long-term breeder, with a lapse in breeding in July and August (Dallas area). Littleton (1979; see note under Size) took gravid females in July in the Navasota River with minimum shell lengths of 23 mm. Females with glochidia were found in B.A. Steinhagen Reservoir, Tyler County, in early May; in Lee County in May and June; and in Mussel Shoal Creek, San Jacinto County, in July, but females collected in Texas September through November were not gravid [RGH]. Females with glochidia were observed extending relatively long caruncles and vigorously waving them about suggesting possible use as a fish-attracting device [RGH].

GLOCHIDIA: Shells small, rounded, hinge line straight, 0.174 mm shell length, 0.194 mm shell height, 0.115 mm along the hinge line, dark tan in color with a rusty tint [RGH].

HOSTS: Warmouth (Lepomis gulosus) and longear sunfish (L. megalotis) (Stern and Felder 1978).

ECONOMIC IMPORTANCE: None.

COMMENTS: Texas lilliput has been reported as externally less silky in appearance than lilliput. Vidrine (1993) considered Texas lilliput as common in large rivers, lakes, and ponds and lilliput as primarily a species of creeks.


TEXAS LILLIPUT
Toxolasma texasensis
Howells (unpublished)
Neck (unpublished)
Neck (1986a)
Neck (1987a)
Neck (1989b)
Shafer et al. (1992)
Strecker (1931)

PISTOLGRIP
Tritogonia verrucosa

Pistolgrip (Tritogonia verrucosa): Top Guadalupe River, Gonzales County, Texas, August 1993; 81 mm shell length; TPWD. Center Leon River, Commanche County, Texas, October 1993; 161 mm; TPWD. Bottom Sabine River, Upshur County, Texas, March 1992; 130 mm sl; TPWD.

OTHER COMMON NAMES: Buckhorn, peanut, turkeywing.

SYNONYMY: (Strecker 1931; Murray and Leonard 1962; Murray and Roy 1968; Oesch 1984).

Unio verrucosa Rafinesque 1820
Unio tuberculata Barnes 1823
Unio verrucosus, Say 1834
Tritogonia verrucosa, Agassiz 1852
Unio tuberculatus, Call 1885
Tritogonia verrucosa Barnes, Simpson 1899
Quadrula verrucosa (Rafinesque 1820)
Quadrula tuberculata, Ortmann 1912
Tritogonia tuberculata, Simpson 1914

DISTRIBUTION: Occurs from the San Antonio River drainage into systems to the north and east.

DESCRIPTION: (Coker 1919; Murray and Leonard 1962; Valentine and Stansbery 1971; Oesch 1984).

Size: To at least 170 mm shell length in Texas (Littleton 1979); also reported to 154 mm in Missouri (Oesch 1984), 152 mm in Kansas (Murray and Leonard 1962), 191 mm in Illinois (Haas 1941), and 203 mm in the northcentral states (Cummings and Mayer 1992).

Shell: Elongate, quadrate, rhomboidal, females more elongate and slender, and males shorter and wider (some cannot be accurately sexed externally); thinner posteriorly and thicker anteriorly; solid; compressed in males, less so in females; gently curved dorsally, broadly rounded anteriorly and anterio-ventrally, slightly curved to nearly straight ventrally before the posterior ridge, posteriorly obliquely truncated and downturned; beaks low and not rising above the hinge line, beak cavities deep; posterior ridge prominent and extending to the ventral margin; externally heavily pimpled, pustulated, or knobby, fluting in some individuals.

Shell Teeth: Two left pseudocardinal teeth, large, erect, grooved, and triangular; single right pseudocardinal tooth, large, grooved, emarginate, triangular, and with a small anterior denticle; lateral teeth long, curved, and striated.

External Color: Olive-yellow or yellow-brown in young, brown to black in larger specimens; pustules often worn and showing white tips.

Internal Color: White, rarely light purple or pink; iridescent posteriorly. Coker (1919) reported some shells as having a pink tint.

Soft Tissues: White; gills brown; all four gills serve as marsupia.

HABITAT: Pistolgrip may be found on almost any stable substrate (Oesch 1984); it has been reported on rock and hard mud as well as silt and soft bottoms, often buried deeply (Murray and Leonard 1962). Stansbery (1965) characterized it as a species typical of oxygen-rich riffles and runs. Buchanan (1980) reported pistolgrips from still waters to 51.8 cm/second, and specimens were often observed on their sides rather than in the typical position with the posterior portion of the shell up.

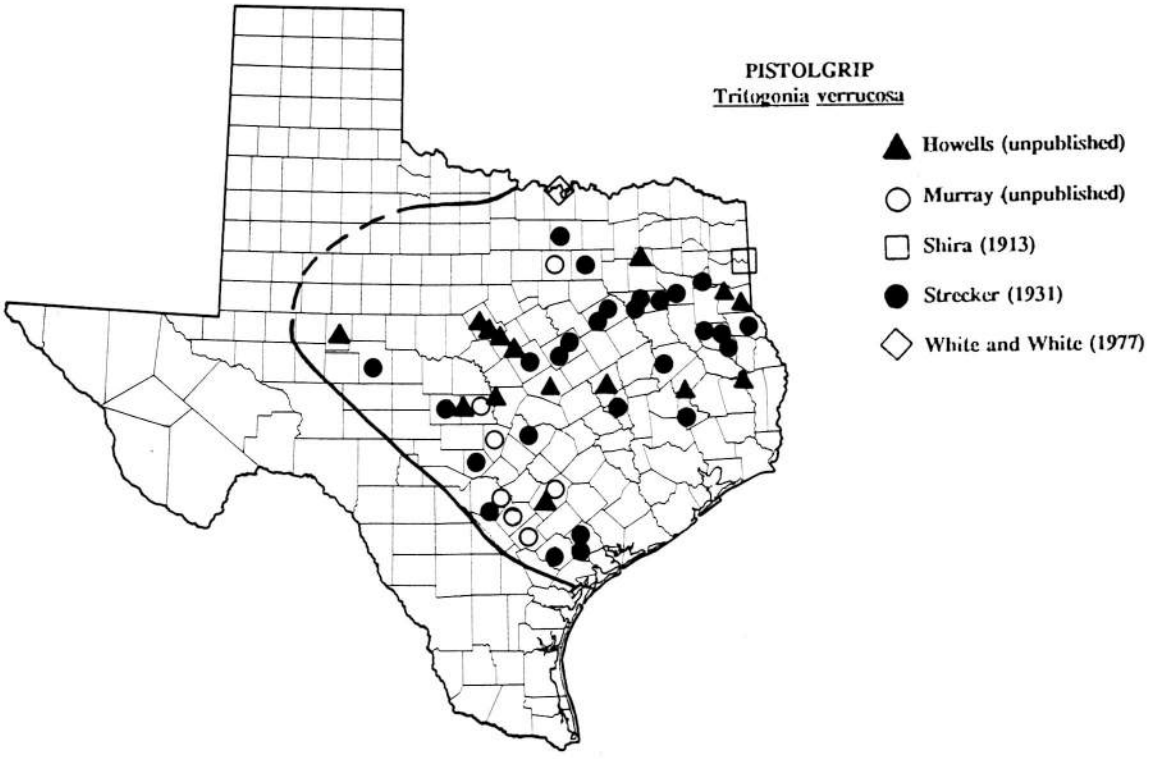
SPAWNING: It has been described as tachytictic (Oesch 1984) and reported gravid in April and June (Surber, cited in Oesch 1984), and July and August (Utterback 1915-16), April through early June in West Virginia and Virginia (Jirka and Neves 1992), and August in central Texas (Littleton 1979). Jirka and Neves (1992) reported an Age-6 female of 58.6 mm shell length as the smallest individual found sexually mature; the smallest mature female indicated by Littleton (1979) from central Texas was 110 mm shell length.

GLOCHIDIA: Shell small, smoothly rounded, 0.122 (0.003 S.D.) x 0.109 (0.003 S.D.) mm, and 0.049 (0.003 S.D.) mm dorsally along the hinge line (Jirka and Neves 1992). Hoggarth (1988) described glochidia as subelliptical to rotund, 0.085-0.094 mm in length, 0.097-0.101 mm in height, and 0.043-0.046 mm dorsally along the hinge line.

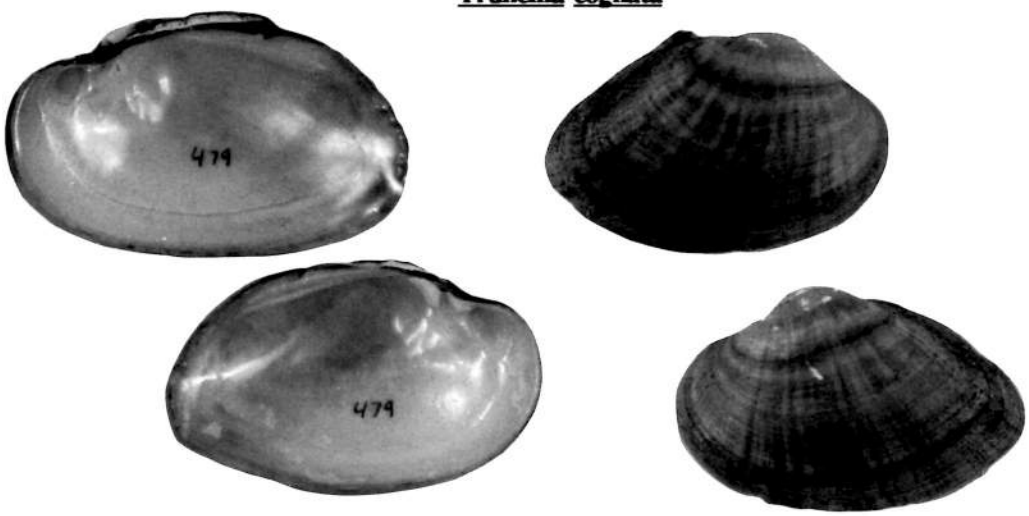
HOSTS: Unreported.

ECONOMIC IMPORTANCE: Pistolgrip was used earlier in the century by the shell-button industry. It was taken elsewhere for shell by the cultured pearl industry, but not apparently significantly harvested for this purpose in Texas. Pistolgrip can produce gem-quality pearls and was one of the primary species taken in the Caddo Lake area during the pearl rush there in the early 1900s (Shira 1913); however, it is not generally sought by pearlers in Texas at the present time.

COMMENTS: Surveys by TPWD 1992 through 1994 found only a single living individual west of the Neches River; only a small number of long-dead shells were located. However, living specimens were taken at a number of sites in the Neches and Sabine River drainages [RGH].


PISTOLGRIP
Tritogonia verrucosa
Howells (unpublished)
Murray (unpublished)
Shira (1913)
Strecker (1931)
White and White (1977)

MEXICAN FAWNSFOOT
Truncilla cognata



Mexican fawnsfoot (Truncilla cognata): Rio Grande, Val Verde County, Texas, January 1972; 45 mm shell length; TUC.

OTHER COMMON NAMES: None.

SYNONYMY: (Simpson 1914).
Unio cognatus Lea 1860
Margaron cognatus Lea 1870
Plagiola cognata Simpson 1900
Truncilla Rafinesque 1820

DISTRIBUTION: Occurs in the Rio Grande drainage.

DESCRIPTION: (Simpson 1914; RGH).

Size: To 44 mm in shell length and 28 mm in height (Simpson 1914); to 45 mm [HDM].

Shell: Elliptical, convex; solid; inflated; valves inequilateral; dorsal margin slightly curved, ventral margin slightly curved, anterior margin rounded, posterior margin obliquely truncated; beaks high, beak cavities moderately shallow; posterior ridge well developed; externally smooth.

Shell Teeth: Two left pseudocardinal teeth triangular, ragged, with the anterior tooth smaller; single right pseudocardinal tooth triangular and pointed; lateral teeth short, 36% shell length; upper-most of the two left lateral teeth is smaller.

External Color: Yellow-green with darker rays; shiny.

Internal Color: Bluish-white or silvery; iridescent posteriorly.

Soft Tissues: Unreported.

HABITAT: Unreported.

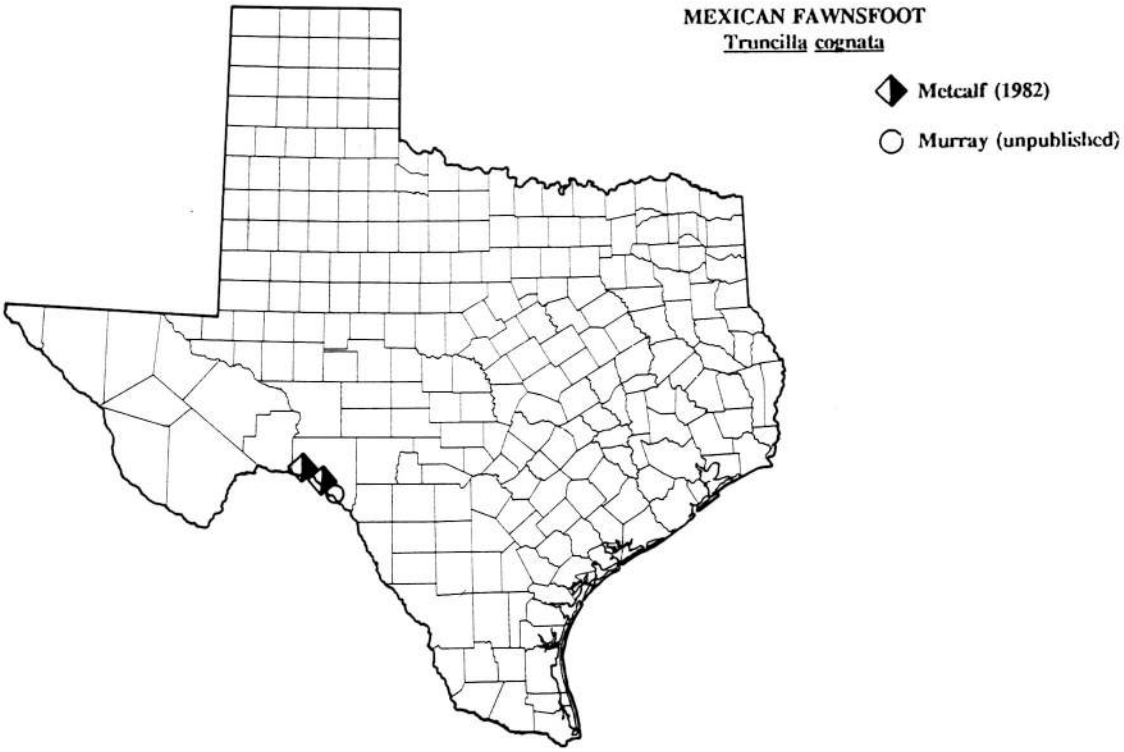
SPAWNING: Unreported.

GLOCHIDIA: Unreported.

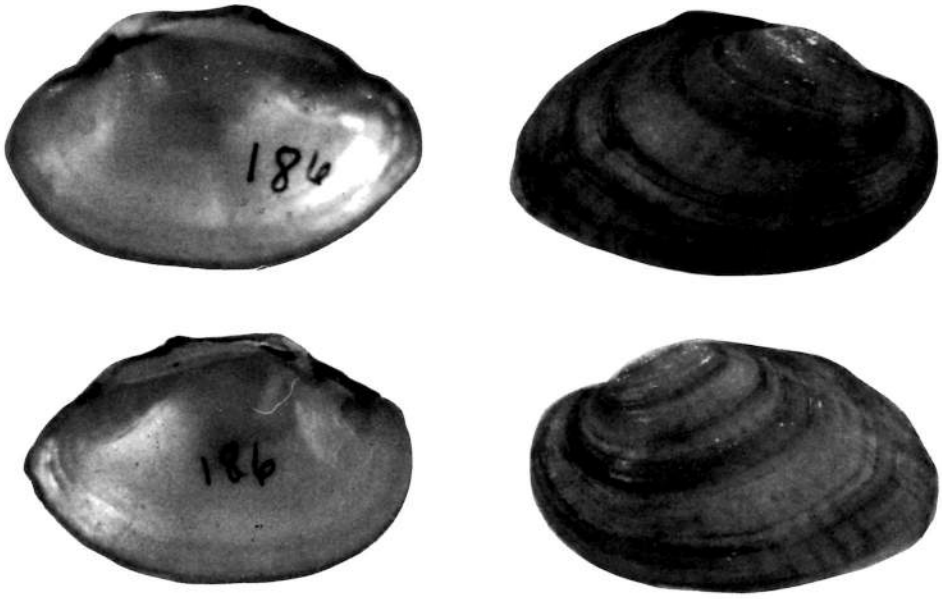
HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

COMMENTS: Mexican fawnsfoot was previously considered endangered by some authorities (Neck 1984), and the American Fisheries Society currently considers it endangered (Williams et al. 1993). Shells are reportedly somewhat heavier than Texas fawnsfoot (T. macrodon) or fawnsfoot (T. donaciformis), and more inflated than Texas fawnsfoot (Simpson 1914).



FAWNSFOOT
Truncilla donaciformis



Fawnsfoot (Truncilla donaciformis): Muskingum River, Ohio, August 1952; 38 mm shell length; TUC.

OTHER COMMON NAMES: Common fawnsfoot, little pocketbook.

SYNONYMY: (Simpson 1914; Strecker 1931; Murray and Leonard 1962; Oesch 1984).
Unio zigzag Lea 1820 (or 1829)
Unio donaciformis Lea 1828
Plagiola donaciformes, Baker 1898
Amygdalonaias donaciformis (Lea), Utterback 1916
Truncilla Rafinesque 1820
Truncilla donaciformes (Lea), Ortmann and Walker 1922

DISTRIBUTION: Occurs from the San Jacinto and Trinity River drainages into systems to the north and east.

DESCRIPTION: (Simpson 1914; Murray and Leonard 1962; Oesch 1984; Fuller 1985).

Size: Reported to 74 mm in Missouri (Oesch 1984), 51 mm in Kansas (Murray and Leonard 1962), and 61 x 36 mm in Oklahoma (Valentine and Stansbery 1971).

Shell: Oval to nearly triangular, oblong-ovate, or elliptical; stout; moderately inflated; thicker anteriorly; dorsal margin nearly straight to slightly convex, ventral margin curved, anteriorly rounded, posteriorly straight, appearing somewhat posterio-ventrally pointed (males more pointed than females); beaks narrow and raised above hinge line, beak cavities reported both as shallow and deep; posterior ridge broadly rounded; growth-rest marks appear as shallow concentric grooves, disk not sulcate.

Shell Teeth: Two left pseudocardinal teeth erect, divergent, rough, and emarginate; single right pseudocardinal tooth erect, grooved, and emarginate; lateral teeth moderately long, slightly curved, roughened, and fairly striated; upper left tooth smaller than the ventral tooth.

External Color: Tan, yellow-green to olive; older shells with chevron- or arrowhead-shaped markings or zig-zag lines, changing to fine green or brown rays.

Internal Color: Bluish-white, silvery-white to nearly salmon; iridescent posteriorly.

Soft Tissues: Off-white; mantle edge black.

HABITAT: It has been reported from small and large rivers (Oesch 1984), especially on sand, mud, rocky mud, and sand and gravel (Murray and Leonard 1962). Fawnsfoot has also been reported from silt and cobble bottoms, in waters 2.5-152 cm in depth, and from still to swiftly flowing conditions (Buchanan 1980).

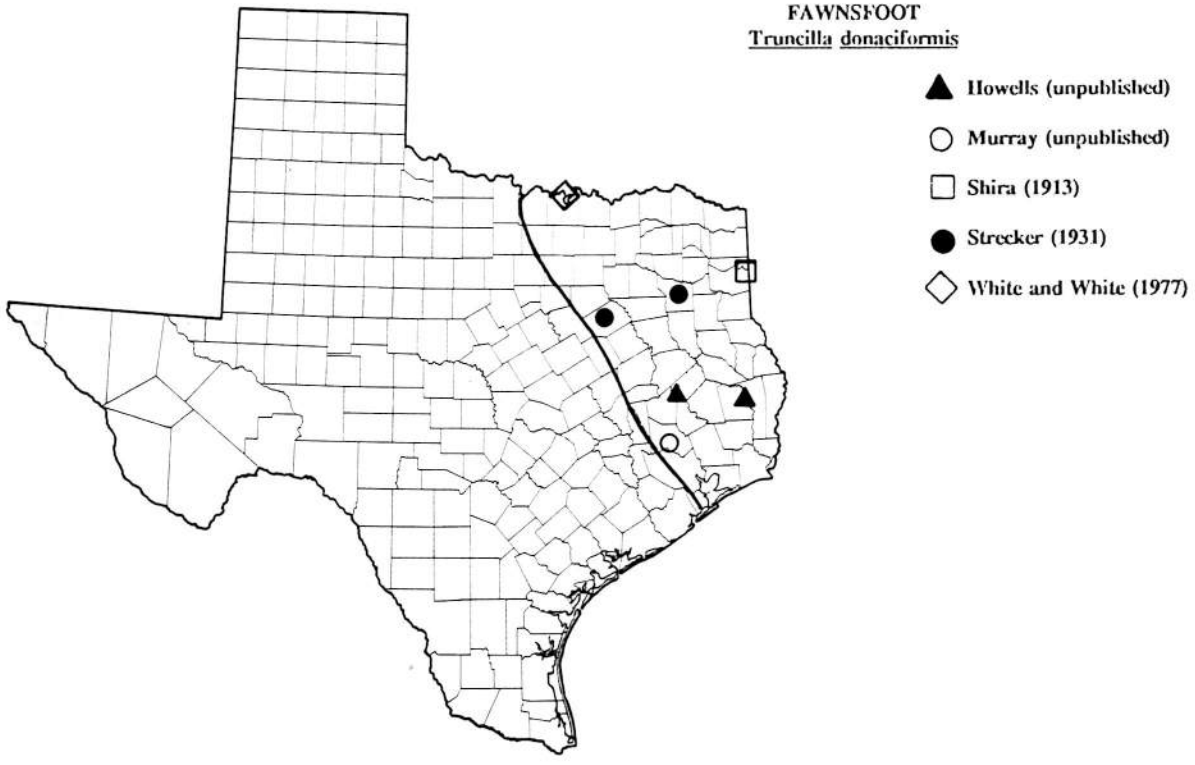
SPAWNING: Baker (1928) indicated breeding season was not clear; Utterback (1915-16) suspected fawnsfoot was probably not bradytictic. Spawning was recorded in May and June (Utterback 1916), June (Ortmann 1919), and August (Surber 1913) elsewhere, but has not been reported for Texas waters.

GLOCHIDIA: Shell described as the smallest glochidium reported, 0.600 [sic; 0.060] x 0.063 mm, semicircular, spineless, hinge line short and slightly undulate (Utterback 1915-16).

HOSTS: Commonly on freshwater drum (Aplodinotus grunniens), and rarely on sauger (Stizostedion canadense) (Surber 1913).

ECONOMIC IMPORTANCE: None.

COMMENTS: Fawnsfoot is more elongate and less triangular than deertoe (T. truncata) (Simpson 1914), slightly more inflated than Texas fawnsfoot (T. macrodon), and not found in the Rio Grande where Mexican fawnsfoot (T. cognata) occurs. Taxonomic validity of all three species may be questionable.



TEXAS FAWNSFOOT
Truncilla macrodon

Texas fawnsfoot (Truncilla macrodon): Both rice canal, near Ancola, Fort Bend County, Texas, August 1970; left 45 mm shell length; right 40 mm; HMNS.

OTHER COMMON NAMES: None.

SYNONYMY: (Simpson 1914; Strecker 1931).

Unio macrodon Lea 1859
Margaron macrodon Lea 1870
Plagiola macrodon, Simpson 1900
Truncilla Rafinesque 1820
Truncilla macrodon Lea, Strecker 1931

DISTRIBUTION: Occurs in the Colorado, Trinity, and Brazos drainages.

DESCRIPTION: (Simpson 1914; RGH).

Size: To 45 mm shell length and 27 mm shell height (Simpson 1914); to 55 mm [RGH].

Shell: Ovate, long; slightly compressed; relatively thin to moderately thick; subsolid; dorsal margin slightly curved, ventral and anterior margins curved, posterior margin round pointed (females fuller posterio-ventrally and more truncated; males more pointed posteriorly); beaks slightly elevated, compressed, and flattened, beak cavities very shallow; posterior ridge broadly rounded; externally smooth.

Shell Teeth: Two left pseudocardinal teeth triangular, compressed, second tooth much higher and more molar-like than first, somewhat C-shaped when viewed laterally; single right pseudocardinal tooth triangular, compressed; two left lateral teeth short, compressed, 29-30% shell length; single right lateral tooth somewhat compressed, moderately high, nearly straight, posterior edge smooth in two specimens but serrate in one individual.

External Color: Dirty- or smoky-green, tan, brown, yellow-brown, reddish-brown; pattern of broken rays often made of irregular blotches, inverted Vs, or zig-zag markings; zig-zag markings sometimes present between rays; slightly shiny.

Internal Color: Bluish-white to white; iridescent posteriorly; some thin shells show external ray patterns internally.

Soft Tissues: Unreported.

HABITAT: Unreported.

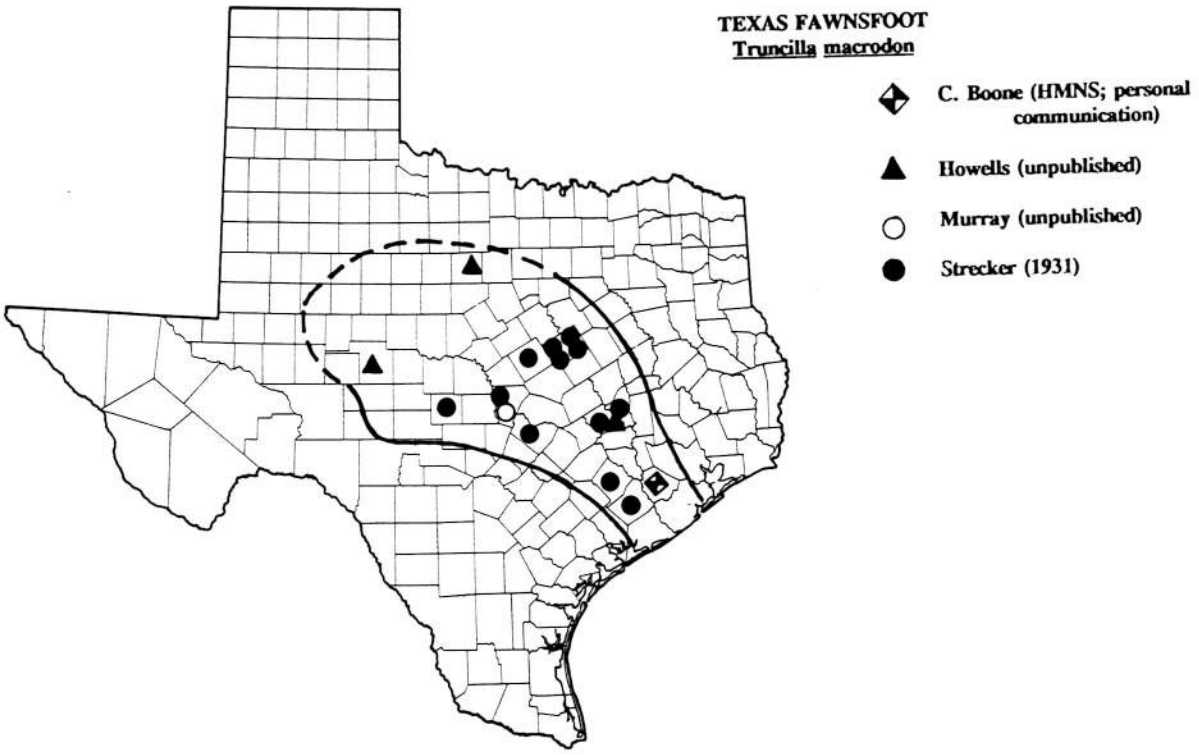
SPAWNING: Unreported.

GLOCHIDIA: Unreported.

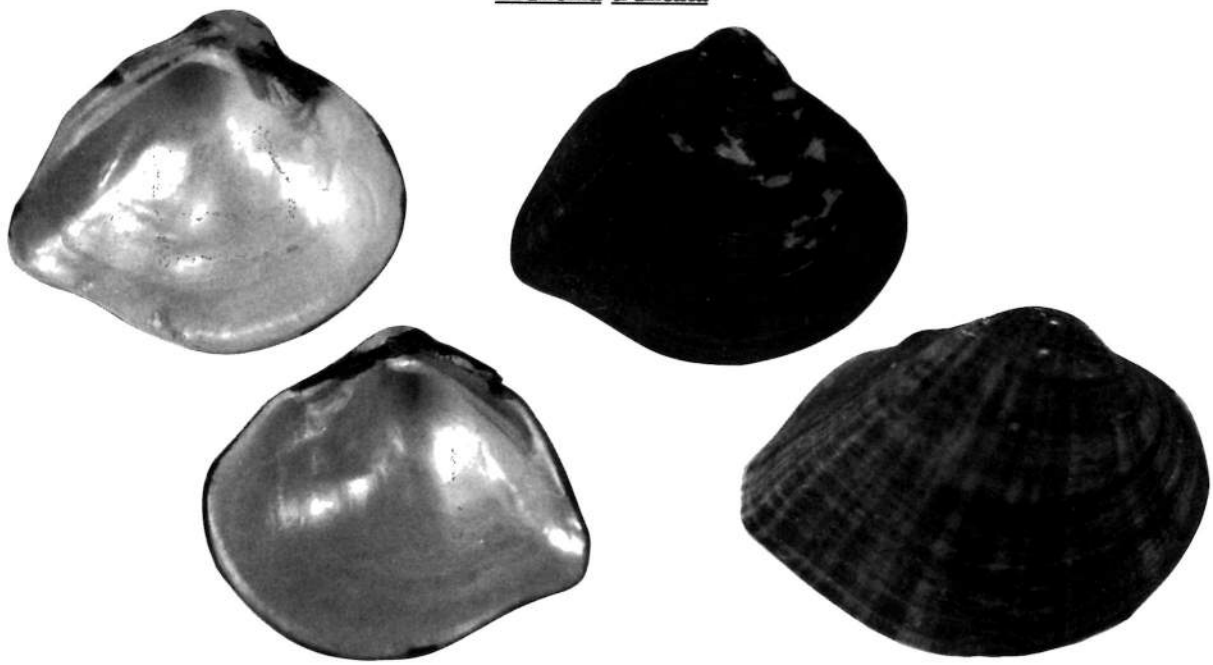
HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

COMMENTS: Texas fawnsfoot is less inflated, less pointed, less vividly colored, and somewhat longer than fawnsfoot (T. donaciformis) (Simpson 1914). The American Fisheries Society considers Texas fawnsfoot endangered (Williams et al. 1993).



DEERTOE
Truncilla truncata



Deertoe (Truncilla truncata): Left and top right Sabine River, Rains County, August 1993; 60 mm shell length; TPWD. Right Salt River, Tennesseee, July 1980; 65 mm; TUC.

OTHER COMMON NAMES: Deerhorn.

SYNONYMY: (Murray and Leonard 1962; Oesch 1984).

Truncilla truncata Rafinesque 1820
Unio elegans Lea 1831
Unio truncatus Raf. = U. donaciformis Lea = U. elegans Lea, Conrad 1835
Plagiola elegans, Baker 1898
Amygdolonaias elegans (Lea), Ortmann 1912
Amygdolonaias truncata (Rafinesque), Utterback 1916
Truncilla truncata Rafinesque, Parmalee 1967

DISTRIBUTION: Occurs from the San Jacinto River system into drainages to the north and east.

DESCRIPTION: (Murray and Leonard 1962; Valentine and Stansbery 1971; Oesch 1984; Fuller 1985).

Size: To 60 mm shell length in Texas [RGH]; reported to 53 mm in Missouri (Oesch 1984), 76.2 mm in Kansas (Murray and Leonard 1962), and 75 x 55 mm in Oklahoma (Valentine and Stansbery 1971).

Shell: Triangular, height 68-79% length; somewhat compressed; stout; thickest anteriorly; dorsal, ventral, and anterior margins rounded, posteriorly straight above (obliquely truncated) and strongly angled to a point below; beaks narrow and raised above the hinge line (nearly centered on some specimens), beak cavities shallow; posterior ridge sharp posteriorly, with an excavated anterior sulcus and radial furrows; externally more or less smooth except for concentric growth rings, some of which may form concentric ridges.

Shell Teeth: Two left pseudocardinal teeth tall, rough, emarginate, compressed, and nearly parallel; single right pseudocardinal tooth triangular, and emarginate, with a small, lamellar tooth or denticle anteriorly; lateral teeth short, striated, and slightly curved.

External Color: Yellow-brown to brown, dark brown to black in older individuals; often with bars, flecks, or other markings on the beak; typically with thin green rays often in groups, or with a dark green zig-zag pattern or spots, some specimens rayless; dark concentric growth marks sometimes present.

Internal Color: Silvery-white, white, or rarely pink; iridescent posteriorly.

Soft Tissues: Off-white.

HABITAT: Deertoe has been reported from a variety of substrates from mud and gravel to large rocks; in depths from several cm deep; usually in swift water (Oesch 1984). It has also been reported on bottoms from silt to cobble, 2.5-152 cm deep, in standing waters to flows of 457 cm/second, and in small to large rivers (Buchanan 1980).

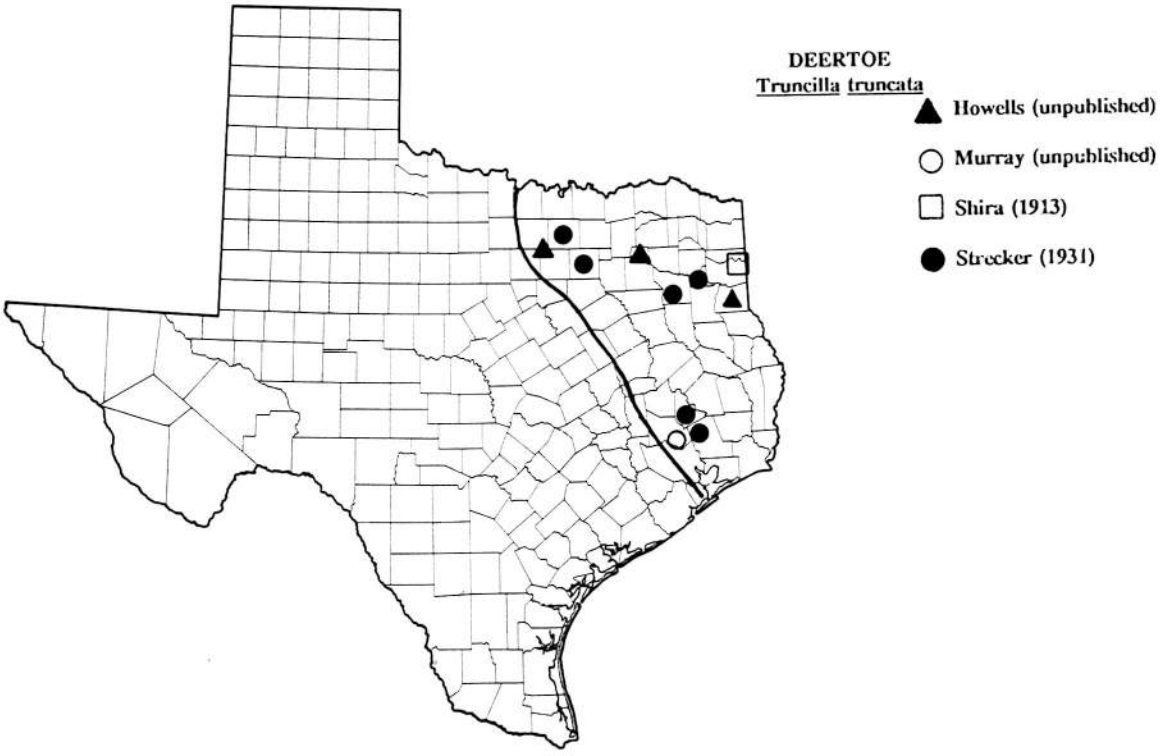
SPAWNING: It has been described as bradytictic (Lefevre and Curtis 1912); gravid females have been reported in May and July (Surber 1912).

GLOCHIDIA: Shell only slightly larger than fawnsfoot (T. donaciformis), 0.060 x 0.070 mm, otherwise identical (Utterback 1915-16).

HOSTS: Sauger (Stizostedion canadense) and freshwater drum (Aplodinotus grunniens) (Fuller 1978).

ECONOMIC IMPORTANCE: None.

COMMENTS: Deertoe is the most geographically widespread of the Truncilla species occurring in Texas. Valentine and Stansbery (1971) indicated the height-to-length ratio was less in deertoe than in fawnsfoot and the posterior ridge was higher in deertoe.



TAPERED PONDHORN
Uniomerus declivis

Tapered pondhorn (Uniomerus declivis): Left and center Giddings State School Lake, Lee County, Texas, October 1993; 111 mm shell length; TPWD. Right Brazos Bend State Park, Fort Bend County, Texas, November 1980; 121 mm; HMNS.

OTHER COMMON NAMES: Pondhorn.

SYNONYMY: (Simpson 1914; Strecker 1931).

Unio declivis Say 1831
Margarita declivis Lea 1836
Margaron declivis Lea 1852
Elliptio tetralasmus manubius Gould, Frierson 1927
Elliptio declivis Say 1831, Strecker 1931
Unio tetralasmus variety declivis, Simpson 1900
Unio manubius = Unio declivus, Morrison 1977

DISTRIBUTION: Occurs in all major drainages; reported from Louisiana and Alabama (Simpson 1914).

DESCRIPTION: (Simpson 1914; Strecker 1931; Neck and Metcalf 1988; RGH).

Size: To 121 mm shell length in Texas [RWN]; reported to 74 x 39 (Simpson 1914).

Shell: Elongate-quadrate; stout, but relatively thin; dorsally slightly curved, rounded anteriorly, ventrally straight or nearly straight, obliquely truncated posteriorly; posterio-ventral projection exaggerated; beaks low, beak cavity shallow; posterior ridge high, narrow, rounded, standing out from the rest of the shell; posterior slope with a wide furrow; externally "flaggy" or weak and flaky, sulcated, and rough.

Shell Teeth: Two left pseudocardinal teeth thin, somewhat compressed, anterior tooth pointed, posterior tooth more or less triangular with rough margin; single right pseudocardinal tooth, erect, pyramid shaped with a small anterior denticle; lateral teeth moderate length, relative thin, straight or nearly so, convergently angled with respect to ventral margin.

External Color: Dark brown to black, not glossy.

Internal Color: Whitish, sometimes purple-tinted.

Soft Tissues: Foot white, mantle tan, gills brown but paler yellowish-brown when gravid; marsupia in outer gills only [RGH].

HABITAT: This species is typical in lentic waters with clay bottoms; it may be adapted to intermittent streams and withstands desiccation (Neck and Metcalf 1988). Tapered pondhorn is often found in beds with larger, heavier mussel species (Strecker 1931).

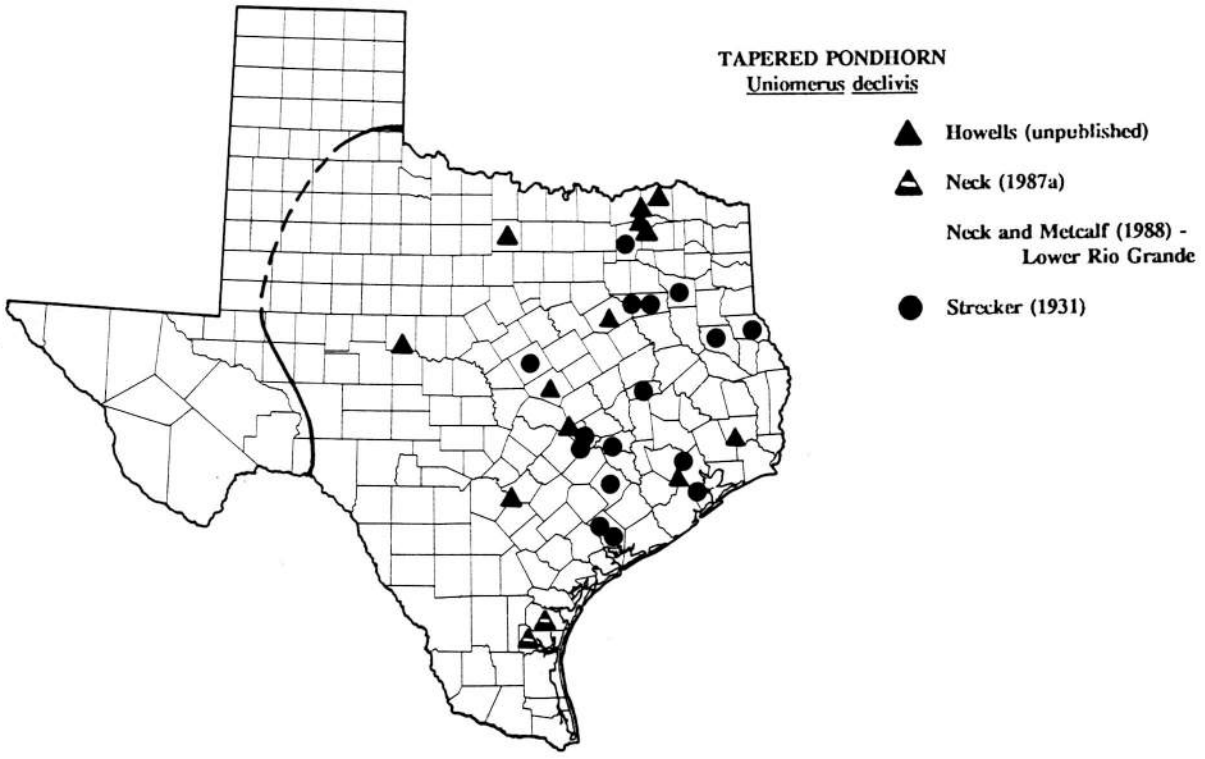
SPAWNING: Females with glochidia were taken in Lee County, Texas, in late May and in the Middle Sulphur River, Franklin County, Texas, in late June [RGH].

GLOCHIDIA: Shells spatulate to somewhat pear-shaped, hinge nearly straight, 0.142 mm shell length, 0.192 mm shell height, 0.077 mm along hinge line, slightly rusty in color [RGH].

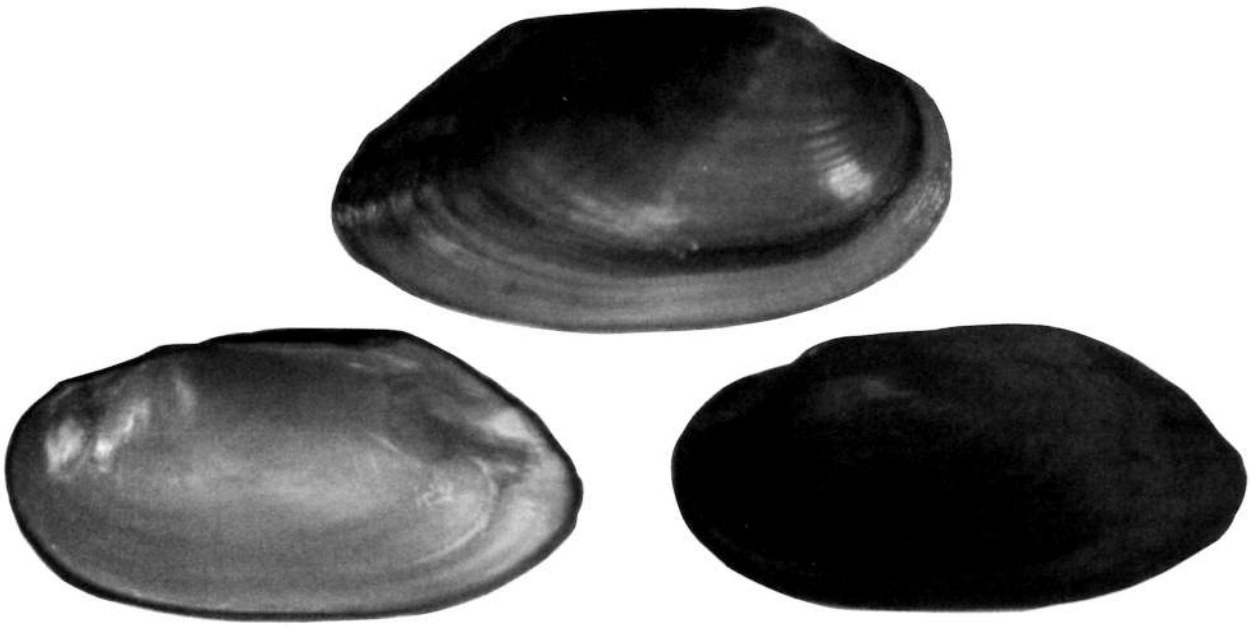
HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

COMMENTS: Tapered pondhorn was described by Simpson (1914) as distinctive, but not very abundant. It is similar to pondhorn (U. tetralasmus) but differs in being rougher and more dull externally (smoother and glossier in pondhorn), having lateral teeth convergent with the ventral margin (more nearly parallel in pondhorn), and being more sharply angled posteriorly (less so in pondhorn).



PONDHORN
Uniomerus tetralasmus



Pondhorn (Uniomerus tetralasmus): Camp Creek Reservoir, Robertson County, Texas, March 1992; top 77 mm shell length; bottom 80 mm; TPWD.

OTHER COMMON NAMES: None.

SYNONYMY: (Strecker 1931; Murray and Leonard 1962; Oesch 1984).

Unio tetralasmus Say 1830
Unio camptodon Say 1832
Unio jamesianus Lea 1857
Unio symmetricus Lea 1845
Unio sayi Ward (in Tappan) 1839
Unio camptodon, Call 1885
Unio camptodon variety camptodon, Simpson 1900
Uniomerus tetralasmus (Say), Ortmann 1912

DISTRIBUTION: Usually occurs from the Trinity River drainage into systems to the north and east. Additionally, specimens from Petronila Creek, Nueces County, and West Squirrel Creek, Medina County, in the Trinity University collection have been identified as this species [HDM], as has a specimen from an oxbow lake adjacent to the San Marcos River, Gonzales County, Texas [RGH] and others reported by Strecker (1931) from the Brazos and lower Guadalupe River drainages. Clarke (1938) reported the species from Palo Duro Canyon, Armstrong County.

DESCRIPTION: (Murray and Leonard 1962; Buchanan 1980; Oesch 1984).

Size: To 141 mm shell length in Texas (Littleton 1979); also reported to 123 mm in Missouri (Oesch 1984), 114.3 mm in Kansas (Murray and Leonard 1962), and 125 x 63 mm in Ohio (Valentine and Stansbery 1971).

Shell: Oblong, elongate-quadrate; stout, but relatively thin and moderately solid; compressed to moderately inflated; dorsal margin slightly curved, rounded anteriorly, obliquely truncated posteriorly, ventrally straight; beaks reported both as low, and only slightly above hinge line, and as elevated, beak cavities

shallow; posterior ridge rounded and not prominent, two parallel grooves dorsal to the posterior ridge with a slightly raised area in between; more or less smooth externally, or with feeble sulcations.

Shell Teeth: Two left pseudocardinal teeth, low, thin, divergent, striated, and parallel to the hinge line; single right pseudocardinal tooth, erect, pyramid-shaped, and with a low denticle anteriorly; lateral teeth short, thin, low, and slightly curved.

External Color: Yellow-brown, light brown, tan, dark brown to black; rayless; subglossy; some specimens banded with concentric rings of lighter or darker colors.

Internal Color: Bluish-white; iridescent posteriorly.

Soft Tissues: Off-white to white; gills brown.

HABITAT: Pondhorn prefers mud-bottom lakes (Oesch 1984); it occurs in ponds, lakes, and small streams to medium-sized rivers on soft or hard bottoms (Murray and Leonard 1962). It has also been found in Texas in oxbow lakes and small impoundments [RGH]. Neck (1982b) indicated pondhorn in Texas was typically found in still waters, and was tolerant of lengthy periods of drought; Neck (1989a) observed the species generally does not persist in large, permanent lakes. Coker (1919) reported specimens being plowed up alive in a pond three months after it had gone dry.

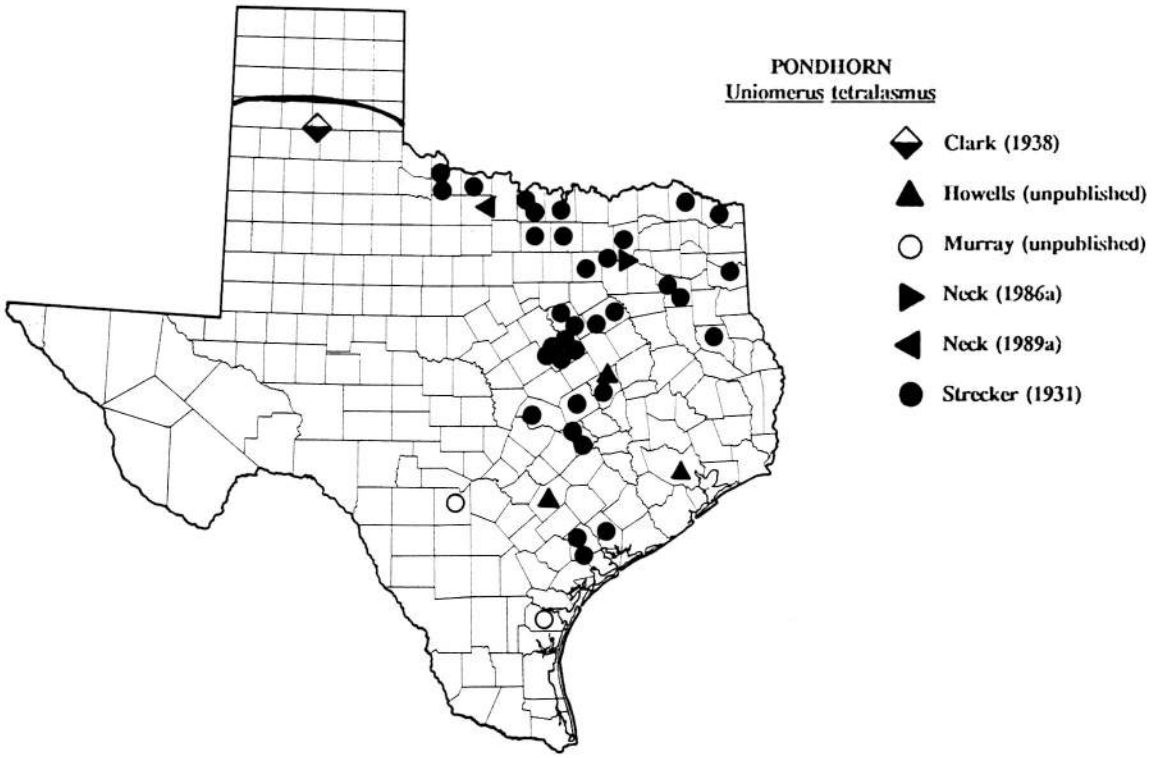
SPAWNING: Spawning is poorly known. Utterback (1915-16) suggested it was probably not tachytictic based on gravid females taken in May and August. Littleton (1979) found gravid females in the Navasota River, Texas, in April and May, with a minimum size of 84 mm shell length.

GLOCHIDIA: Shell medium-sized, 0.160 mm shell length and 0.210 mm shell height, spatulate, very regular in outline, hinge line short and straight (Utterback 1915-16).

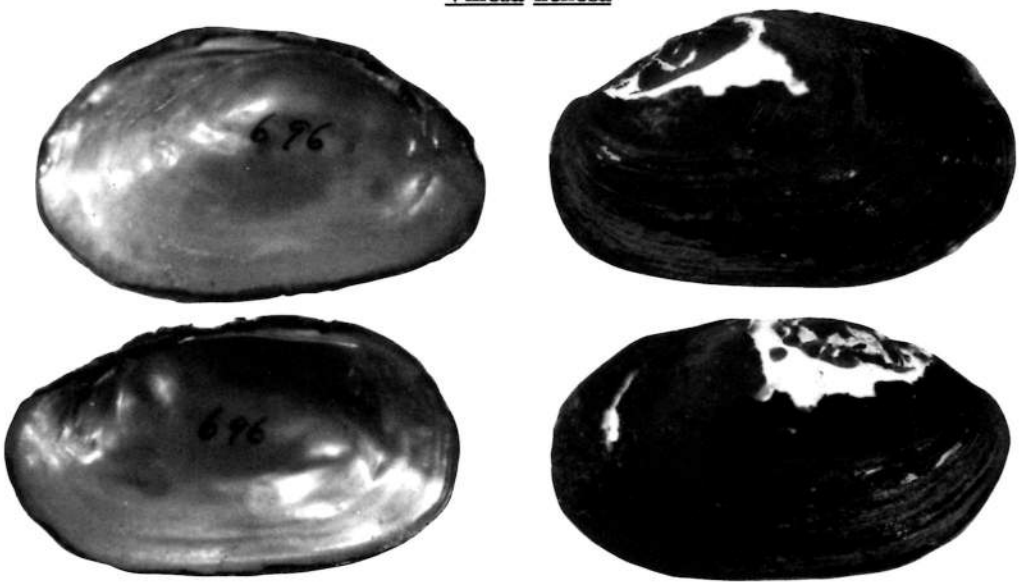
HOSTS: Golden shiner (Notemigonus crysoleucas) (Hoggarth 1992).

ECONOMIC IMPORTANCE: None.

COMMENTS: Pondhorn may be confused with pond mussel (Ligumia subrostrata) which is posteriorly more centrally pointed in males and dorsally pointed in females (ventrally pointed in pondhorn)[RGH], and which lacks the concentric rings that turn up sharply at the beak as in pondhorn (Murray and Leonard 1962). It may also be confused with tapered pondhorn (U. declivis) which has a more pronounced posterior ridge, is externally more rough or flaggy (less-well defined posterior ridge and subglossy in pondhorn), and has more convergent lateral teeth (more nearly parallel in pondhorn).


PONDHORN
Uniomerus tetralasmus
Clark (1938)
Howells (unpublished)
Murray (unpublished)
Neck (1986a)
Neck (1989a)
Strecker (1931)

LITTLE SPECTACLECASE
Villosa lienosa



Little spectaclecase (Villosa lienosa): Ochlochonee River, Leon County, Florida, July 1981; 58 mm shell length; TUC.

OTHER COMMON NAMES: Black creekshell.

SYNONYMY: (Strecker 1931; Murray and Roy 1968; Oesch 1984).

Unio lienosus Conrad 1834
Margarita lienosus Lea 1836
Unio saxeus Conrad 1840
Unio caliginosus Lea 1845
Margaron lienosus Lea 1852
Margaron saxeus Lea 1852
Margaron calaginosus Lea 1852
Unio fontanus Conrad 1866
Lampsilis nigerrimus (Lea 1852)
Lampsilis concestator (Lea 1857)
Lampsilis lienosus, Simpson 1900
Eurynia (= Micromya) lienosa (Conrad), Ortmann 1912
Villosa (= Micromya) lienosa, Parmalee 1967

Taxonomic confusion exists within the genus. Some authors list Villosa lienosa-complex (e.g., Burch 1973).

DISTRIBUTION: Typically occurs from the San Jacinto River drainage into systems to the north and east.

DESCRIPTION: (Burch 1973; Littleton 1979; Oesch 1984; RGH).

Size: Reported to 67 mm shell length in Missouri (Oesch 1984) and 64 mm in the northcentral states (Cummings and Mayer 1992).

Shell: Oval, oblong, ovate; stout; thickness rather uniform; moderately inflated; dorsal and ventral margins straight or slightly curved, anteriorly rounded, posteriorly rounded but tapering (somewhat more pointed in males); beaks broad, low, and only slightly above the hinge line, beak cavities moderately deep; posterior ridge broadly rounded; externally somewhat smooth except for concentric growth lines.

Shell Teeth: Two left pseudocardinal teeth erect, triangular, divergent, and emarginate; single right pseudocardinal tooth, erect, striated, columnar, emarginate, and with a high denticle anterior to the main tooth; lateral teeth short and curved.

External Color: Yellow-brown or greenish-brown to light brown, darker with age; with continuous green rays, even in adults; some specimens nearly black with little suggestion of rays.

Internal Color: Pink, occasionally creamy- or bluish-white; iridescent throughout.

Soft Tissues: Dirty white; gills brown.

HABITAT: This species has been reported from creeks, rivers, and reservoirs in Texas [RGH].

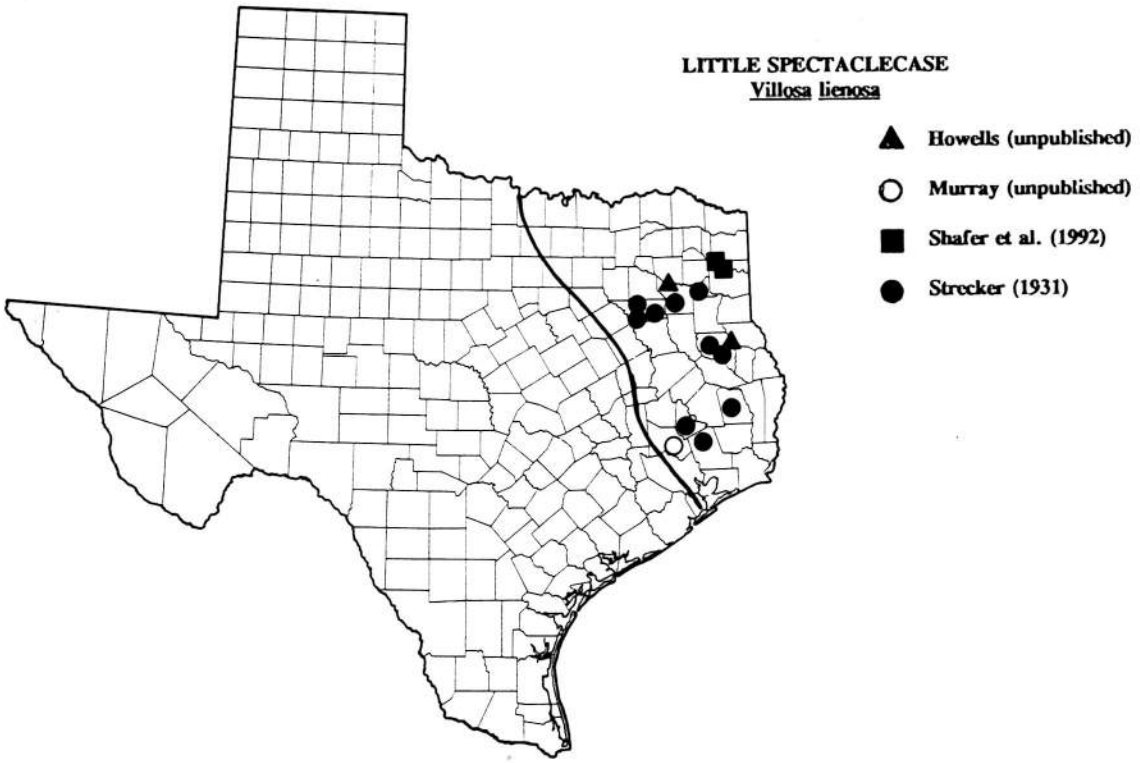
SPAWNING: Reproductive period has been reported as not known (Oesch 1984).

GLOCHIDIA: Shell large, subovate, 0.220 mm length and 0.270 mm height (Utterback 1915-16).

HOSTS: Unreported.

ECONOMIC IMPORTANCE: None.

COMMENTS: Vidrine (1993) characterized this species as highly variable and abundant in headwater creeks in Louisiana.



Family: Corbiculidae
ASIAN CLAM
Corbicula sp(p).

Asian clam, Corbicula sp(p).: Top left Lake Gonzales, Gonzales County, Texas, July 1992; 34 mm shell length; TPWD. Bottom left Little Brazos River, Robertson County, Texas, August 1993; 27 mm; TPWD. Center Lake Gonzales, Gonzales County, Texas, August 1992; 48 mm; TPWD. Top right San Maros River, Comal County, Texas, May 1992; 26 mm; TPWD. Bottom right Utopia Lake, Uvalde County, Texas, May 1993; 25 mm; TPWD.

OTHER COMMON NAMES: Asiatic clam, corbicula clam.

SYNONYMY: (Sinclair and Isom 1963; Morton 1979)

Cyrena fluminea Muller 1774
Cyrena manillensis Philippi 1841
Cyrena orientalis var. javanica Mousson 1849
Corbicula venustula Prime 1864
Corbicula vicina Heude 1880
Corbicula leana Prime 1884
Corbicula fluminea (in part) Prashad 1929
Corbicula manillensis Prashad 1929
Corbicula leana Kuroda 1938
Corbicula awaiiensis Kuroda 1938
Corbicula producta Kuroda 1938
Corbicula papyracea Kuroda 1938
Corbicula vicina Oyama 1943
Corbicula papyracea Oyama 1943
numerous others

Genus Corbicula was first recognized in 1772 as Tellina (Sinclair and Isom 1963). When initially reported in North America, Asian clam was given as Corbicula fluminea (Muller 1774). Later, others listed it as C. manilensis (Philippi 1841); also spelled manillensis. Ultimately the American Fisheries Society (Turgeon et al. 1988) returned to the use of C. fluminea; however, others have defined it as C. leana Prime 1864 (Oesch 1984). Further, Hillis and Patton (1981) presented electrophoretic evidence suggesting two species may be present in Texas; Fontanier (1982) also suggested the presence of two forms in Texas. Morton (1986)

concluded there were only two species in Asia, C. fluminea and C. fluminalis, with C. leana and C. manilensis as junior synonyms of C. fluminea. Exact definition of which and how many species are actually present in Texas and North America remains unclear.

Numerous additional species in the genus have been described (Habe 1971; Hirase 1951; Sinclair and Isom 1963). Sinclair and Isom (1963) reported by 1882 as many as 150 species had been described. Prashad (1929) listed 64 synonyms of C. fluminea alone; and when Pilsbry (1901) described yet another Japanese species, he began with "it fills me with sadness to add another Corbicula...". Sinclair and Isom (1963) indicated there was much local variation within species, and Pilsbry (1907) observed differences within the genus were "not strongly developed." Sinclair and Isom (1963) considered the U.S. populations to be manilensis, rather than fluminea, but also felt C. leana and C. japonica were synonyms of C. manilensis.

DISTRIBUTION: Asian clams occur in all major river systems in Texas (Neck 1987b). Members of the genus occur in Japan, Russia, China, the East Indian Islands, Australia, across India and southern Asia to East Africa (Gruver 1968), with species described from South America (Marshall 1924) and introductions of some species outside their native ranges (Sinclair and Isom 1963; Morton 1986). Asian clams were first observed in the Columbia River, Oregon, in 1938 (Dundee and Dundee 1958), and ultimately spread south into California, eastward across the Gulf states and northward up the Mississippi River system and eastern seaboard (Diaz 1974). The exact method of introduction into North America is not known (Gruver 1968). Asian clams were first reported in Texas by Metcalf (1966), with subsequent documentation of its spread across the state (Murray 1971; Britton and Murphy 1977; Baker 1978; Pool and McCullough 1979; Fontanier 1982; Neck 1987b, 1989a, b).

DESCRIPTION: (Sinclair and Isom 1963; Hillis and Patton 1981; Oesch 1984).

Size: Texas specimens reach at least 60 mm shell length (Britton 1982); to 45 mm in Missouri (Oesch 1984), 43 mm in Tennessee (Sinclair and Isom 1963), and 55 mm on the U.S. west coast (Sinclair and Isom 1963). Sinclair and Isom (1963) also reported C. fluminea to 83 mm, C. manillensis to 38 mm, and C. leana to 48 mm elsewhere in the world.

Shell: Oval and nearly equilateral to triangular and inequilateral (shell shape may change with age and environment, called ecophenotypes); solid, strong, though not exceptionally thick, rarely thin; rounded dorsally, anteriorly, ventrally, and posteriorly, slightly round-pointed posterio-ventrally in some larger specimens; beaks may be high or low, but are generally narrow and raised above the hinge line, beak cavities deep; posterior ridge largely absent in small specimens, broadly rounded in some larger individuals; externally dull or glossy, with multiple, three-dimensional concentric rings which may be heavy and widespread or fine and narrowly spaced.

Shell Teeth: Three interlocking cardinal teeth in each valve; two anterior and two posterior lateral teeth in the right valve, and one anterior and one posterior lateral tooth in the left valve; lateral teeth straight or nearly straight, and moderately long, with fine, file-like striations.

External Color: Yellow-green, tan, light brown, dark brown, or black; evenly colored or with alternating, concentric bands of color; juveniles may display one or more rays on beaks, and some very large individuals may also have a rayed appearance; often eroded, especially at beaks.

Internal Color: Typically white, white with purple tints or completely purple, occasionally bicolored, also reportedly salmon-pink; glossy.

Soft Tissues: Off-white or yellowish-white.

HABITAT: Asian clams tolerate a wide variety of habitats including substrates of fine silt, mud, sand, gravel, cobble, and bedrock; in still to rapidly flowing waters; in both turbid and clear waters; and from depths of only a few mm [RGH] to at least 18 m deep (Diaz 1974). Specimens have been observed on soft silt bottoms where the only other bivalves present were light-shell paper pondshells (Anodonta imbecillis), and in waters where other bivalves did not exist [RGH]. C. fluminea tolerates salinities to at least 5 ppt

(Sinclair and Isom 1963); also reported to 15 ppt (Morton 1986). Fontanier (1982) reported densities as great as 3,500/m^2 in Texas waters; densities in excess of 2,200/^{2} were found in the Concho River, Concho County, Texas, 1993 [RGH].

SPAWNING: Species within the genus follow several different reproductive strategies. A summary presented by Sinclair and Isom (1963) indicated: (1) C. leana-group as typically freshwater species, monoecious, incubatory, and producing non-swimming larvae; (2) C. sandai as a freshwater species, dioecious, non-incubatory, and producing non-swimming larvae; and (3) C. fluminea-group as typically estuarine, dioecious, non-incubatory, and producing free-swimming larvae. Additionally, Marshall (1924) listed several species from South America reported as viviparous. Sexes are reportedly separate in U.S. populations (Gross and Cain 1977). More recently, Morton (1986) indicated C. fluminea was often dioecious with a high percentage of hermaphrodites in flowing water and equal percentages of females and hermaphrodites in non-flowing waters. Morton (1986) also reported two spawning peaks in summer.

In general, Asian clams produce eggs and larvae (called trochophores in early development and veligers in later stages) which are held in gill pouches; some species retain developing trochophores and veligers longer than others (Sinclair and Isom 1963; Gross and Cain 1977). Released veligers may float (non-swimming) in the plankton community, crawl about on the bottom, or may swim, depending upon species (Sinclair and Isom 1963). Veligers about 0.200 mm in size have been reported, apparently both in the plankton and crawling about the bottom by means of a foot (Sinclair and Isom 1963). Sinclair and Isom (1963) used the terms marsupial trochophore, marsupial veliger, planktotrophic veliger, and benthic veliger to describe stages between the egg and juveniles. Retention of shelled-veliger stages may have prompted statements about retaining larvae and releasing juveniles (conceptual terminology). Morton (1986) termed the crawling larval stage pediveligers. Specimens examined by TPWD in 1992 were found to contain mature eggs, but no juveniles were found in adult females. None of the Corbicula species produce a parasitic glochidial stage, and none require a fish host. Maturity can occur within the first year at about 6.5 mm (Sinclair and Isom 1963). Spawning has been observed between March and November in U.S. waters (Sinclair and Isom 1963), and commences at 16.7-18.3°C (Gross and Cain 1977).

GLOCHIDIA: None.

HOSTS: None.

COMMERCIAL IMPORTANCE: Asian clams are harvested for human consumption in Asia (Sinclair and Isom 1963) but have little positive importance in the U.S. Some are taken for human consumption and for use as fish bait (Sinclair and Isom 1963), and such uses have been reported in Texas. Living Asian clams have appeared occasionally in the pet trade and both alive and dead in some Oriental grocery stores in Texas [RWN]. Asian clams are eaten by some native fishes including blue catfish (Ictalurus furcatus), channel catfish (I. punctatus), common carp (Cyprinus carpio), freshwater drum (Aplodinotus grunniens), redear sunfish (Lepomis microlophus), and Pacific sturgeon (Acipenser spp.) (Sinclair and Isom 1963); they are also eaten by some waterfowl. Asian clams have been examined as filtration agents for waste-eater purification. However, their importance is generally considered negative. Sinclair (1971) branded them the most costly liability of all exotic mollusca in North America; however, the statement was made before the introduction of zebra mussel (Dreissena polymorpha). Neck (1986b) discussed the relationship of Asian clams and humans in Texas; he reported construction and use of recreational facilities may either enhance or reduce local habitat for Asian clams.

COMMENTS: The method of dispersal across North America has been a bit enigmatic to define. Certainly veligers drifting with flowing waters and older individuals being swept along by flood waters account for distribution to downstream areas. Some minimal number might be distributed accidentally by birds or other animals, and people may have deliberately or accidentally transported others. Even gravel dredging and relocation (including in concrete mixing) has been implicated. None the less, distribution across the continent occurred relatively rapidly.

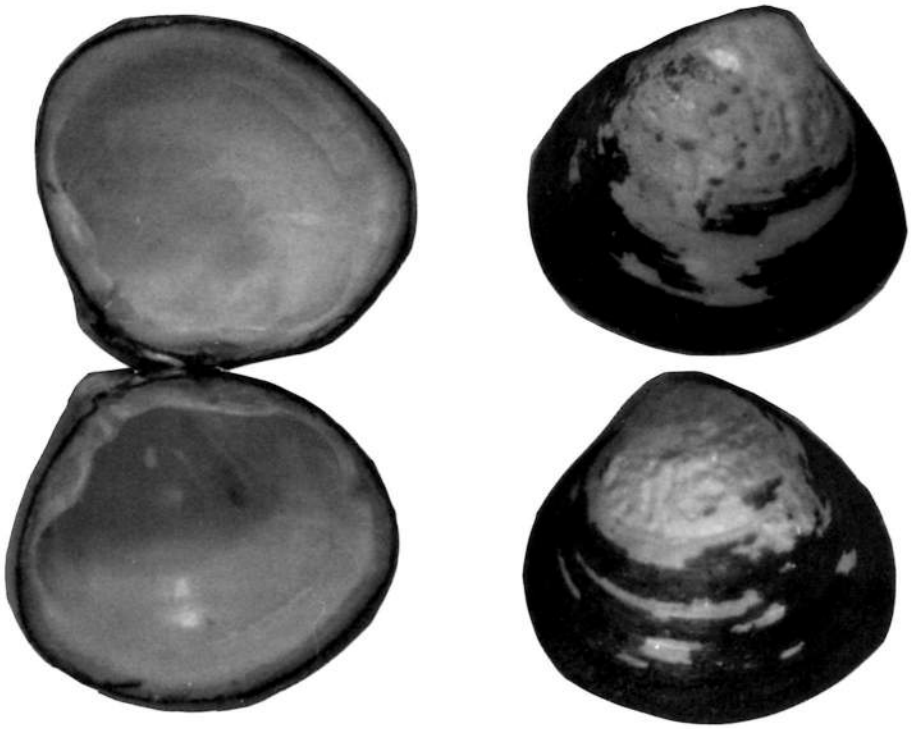
The presence of both anterior and posterior lateral teeth differentiate them from native unionid mussels. Fingernail clams (family Sphaeriidae) typically have one or two left and one right cardinal teeth rather than

three in each valve in Asian clams. Asian clams have bold, heavy, concentric rings which differentiate them from other bivalves found in fresh water in Texas.

Morton (1986) noted two growth rings were produced each year for three years (maximum typical life span).

Note that Asian estuarine clam (Potamocorbula amurensis), which has been introduced into San Francisco Bay, California, is unrelated despite similarities in common and scientific names. It is in the family Corbulidae and has mismatched valves typical of the family where one valve is smaller than the other. Asian estuarine clam reaches about 28 mm shell length and occurs at salinities of 1-33 ppt.

Family: Corbiculidae
CAROLINA MARSHCLAM
Polymesoda caroliniana



Carolina marshclam (Polymesoda caroliniana): Galveston Bay near Frozen Point, Texas, 1991; unmeasured (ca. 35 mm shell length); National Marine Fisheries Service, Galveston, Texas, M.C. Pattillo.

OTHER COMMON NAMES: Marsh clam.

SYNONYMY: (Andrews 1981; Turgeon et al. 1988).
Polymesoda caroliniana (Bosc 1802) also given as 1801

DISTRIBUTION: Occurs from Virginia to Texas (Andrews 1981), typically in coastal areas.

DESCRIPTION: (Morris 1973; Andrews 1981).

Size: To 25-38 mm shell length (Andrews 1981).

Shell: Triangular to nearly round; inflated; equivalved, inequilateral; curved dorsally, anteriorly, posteriorly, and ventrally; beaks inflated and above hinge line, beak cavities moderately deep; posterior ridge broadly rounded and ill-defined; pallial sinus narrow and deep; externally smooth except for weak concentric growth lines; beaks often badly eroded.

Shell Teeth: Each valve with three, small, vertically-positioned, and nearly equal size cardinal teeth; both anterior and posterior lateral teeth present with two posteriorly and one anteriorly.

External Color: Brown to black, sometimes greenish; eroded areas on the beak and elsewhere white; may be glossy; sometimes shows minute scales.

Internal Color: White.

Soft Tissues: Off-white.

HABITAT: Carolina marshclam is typically found in low-salinity coastal marshes or the freshwater reaches of estuaries; it tolerates relatively high salinities (Andrews 1981). It is often found in mud or sand associated with coastal estuarine conditions. Andrews and Cook (1951) reported it in three main habitats: in small depressions in sedge-matted banks; in fine, black silt under algal mats; and between and under rock rip-rap; they found it from fresh water to salinities of 15 ppt.

SPAWNING: Details of spawning behavior, seasons, and early life stages are largely lacking. However, marshclams likely have a free-living veliger stage typical of other estuarine and marine bivalves and therefore do not have a parasitic glochidial stage or require a fish host.

GLOCHIDIA: None.

HOSTS: None.

ECONOMIC IMPORTANCE: None.

COMMENTS: The presence of both anterior and posterior lateral teeth differentiate Carolina marshclam from unionid mussels.

Family: Mactridae
ATLANTIC RANGIA
Rangia cuneata

Atlantic rangia (Rangia cuneata): Left and right Great Bay, New Jersey, 1975; 41 mm shell length; TPWD. Center Gulf of Mexico, northeastern Mexico, October 1992; 70 mm sl; TPWD.

OTHER COMMON NAMES: Common rangia.

SYNONYMY: (Turgeon et al. 1988)
Rangia cuneata (Sowerby 1831)

DISTRIBUTION: Occurs in coastal waters from New Jersey to Mexico (Andrews 1981). C.K. Chandler (University of Texas at San Antonio; pers. comm.) reported large numbers of subfossil shells from the northeastern Mexican coast. Hopkins (1970) listed the species in the Nueces River from Green and Mission lakes, in the Guadalupe River, the San Jacinto-Trinity river delta, and the Neches and Sabine rivers, as well as numerous coastal bays.

DESCRIPTION: (Morris 1973; Andrews 1981).

Size: To 80 mm shell length (Andrews 1981; RGH); often reported reaching greatest size in fresh waters, but the largest specimens taken in Louisiana were found at more saline conditions (Tarver and Dugas 1973). Sometimes given as larger on sand bottoms.

Shell: Obliquely ovate; equivalved, inequilateral; inflated; solid, heavy, thick; curved dorsally, anteriorly, and ventrally, gently curved posteriorly, slightly pointed posterio-ventrally; beaks very high and hooked (unlike any native unionids), beak cavities deep; posterior ridge pronounced; pallial sinus small but distinct; chondrophore deeply excavated; externally sculptured with fine concentric growth rings.

Shell Teeth: Two small, leaf-like cardinal teeth in each valve; with a much larger tooth associated with the proximal end of the anterior lateral teeth; both anterior and posterior lateral teeth present; posterior lateral teeth single in each valve, very long (nearly to the ventral margin), and finely striated dorsally (file-like); anterior lateral teeth single in the left valve, nearly double in the right valve.

External Color: Brown, gray-brown, grayish-white to black.

Internal Color: White; polished.

Soft Tissues: Off-white.

HABITAT: Atlantic rangia occurs in coastal fresh and brackish waters, in river-influenced areas; it is characterized as a brackish-water species (Andrews 1981). It was reported several miles up the Nueces River (Andrews 1981), but may be found in the lower reaches of other rivers as well. Densities of 250/m^2 from the Neches River were indicated by Hopkins (1970), with other reports of 818/m^2 of specimens greater than or equal to 16 mm (Tarver and Dugas 1973) and 1,800/m^2 (Fairbanks 1963).

SPAWNING: This species produces planktonic veliger larvae typical of other marine and estuarine bivalves; it does not have a glochidial stage typical of unionids, and does not require a fish host.

GLOCHIDIA: None.

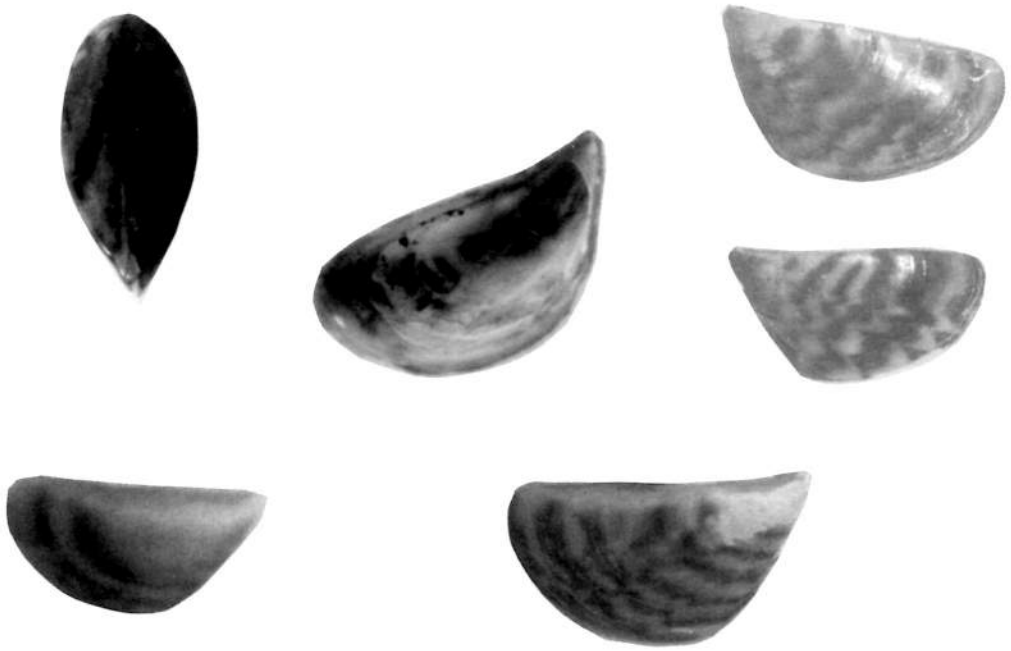
HOSTS: None.

ECONOMIC IMPORTANCE: Native Americans harvested this species for food and tools (McIntire 1958; Aten 1973). Atlantic rangia has been collected (living, recently dead, and fossil) for shell used for road grading and fill, and as a source of calcium carbonate for industrial uses and water purification (Hopkins et al. 1973). The extent of use for these purposes in Texas at present is unreported. Similarly, Atlantic rangia have been commercially harvested for human consumption from as far back as 1893 when their meat was canned in Galveston (Tarver and Dugas 1973), with more recent harvest for meat and shell in the Neches River (Hopkins 1970). Whether this harvest continues at the present time in Texas is undocumented. Atlantic rangia is a staple in the diet of many fishes, crustaceans, and water fowl (Tarver and Dugas 1973).

COMMENTS: An additional species, brown rangia, Rangia flexuosa (Conrad 1840), occurs from Louisiana and Texas to Mexico; it may also occur in low salinity waters, but is primarily a high-salinity species (Andrews 1981); brown rangia (shown below) has short posterior lateral teeth and is more pointed posteriorly (Andrews 1981). The presence of both anterior and posterior lateral teeth readily differentiate both rangias from unionids where only posterior lateral teeth are present, and beaks are higher and more strongly hooked than in native freshwater mussels.

Brown rangia (Rangia flexuosa): Gulf of Mexico near Palacios, Calhoun County, Texas, September 1992; 50 mm shell length; TPWD.

Family: Dreissenidae
ZEBRA MUSSEL
Dreissena polymorpha



Zebra mussel (Dreissena polymorpha): Lake Erie, Michigan, 1990; 12-21 mm shell length; TPWD.

OTHER COMMON NAMES: Triangular clam, many-shaped dreissena.

SYNONYMY: Within the family Dreissenidae, three genera are recognized including Dreissena, Mytilopsis, and Congeria. Two to seven species of Dreissena have been listed, with D. polymorpha and D. rostriformis generally accepted, D. bugensis commonly discussed in published literature, and D. distincta as a nominal species synonymous with or allied to rostriformis (May and Marsden 1992). This family was termed "closed mussels" by Carpenter (1861).

DISTRIBUTION: Zebra mussel is not present in Texas (in the wild) at this time (1994). Originally native to the Black, Caspian, and Azov seas, zebra mussel apparently entered the Great Lakes by way of ship ballast water (Hebert et al. 1989) in 1985 (Strayer 1991) or 1986 (Neary and Leach 1992). It was first found in Lake St. Clair in 1988 and has now spread through the Great Lakes (O'Neill and MacNeill 1991), entered the Hudson and Susquehanna river drainages, and extended down the Mississippi River system as far south as Mississippi, Oklahoma and the Arkansas and Little Rock rivers of Arkansas and Louisiana; other reports place it at Morgan City, Louisiana. Strayer (1991) projected, based upon European distribution, zebra mussels may invade Texas along the Red River, and in the Panhandle and northwestern areas of the state. Sinclair and Isom (1963) predicted zebra mussel would likely extend its range into North America 22-23 years before its arrival. Carpenter (1861) noted zebra mussel was accidentally introduced into England on timber brought from Russia to London.

DESCRIPTION: (Hebert et al. 1989; MacNeill 1991; Hopkins 1990).

Note: Dorsal-ventral and anterior-posterior orientation used for mytilid-shaped bivalves differs from that used for unionid mussels by considering the beak as anterior and the maximum dimension as length; see

Marelli and Gray (1983).

Size: To 40 mm shell length (Hopkins 1990).

Shell: Elongate, sometimes described as boat-shaped; equivalved, but inequilateral; thin; strongly keeled dorsally, flattened ventrally, dorsally pointed at the terminal beak, curved from the beak dorsally and posteriorly; triangular in cross section, with an acute angle laterally from the beak to the ventral margin; beak cavity deep; external ligament located posterior to beak; byssus well developed; anterior adductor muscle and byssal retractor attach to a broad, shelf-like plate (septum) internally below the hinge; pallial line smoothly curved; externally smooth except for fine concentric growth rings.

Shell Teeth: Absent.

External Color: Yellowish- or greenish-tan to brown or black; usually with wavy, angular, concentric bands which are highly variable; some individuals may be completely light or dark; some individuals glossy.

Internal Color: Pale bluish-white; sufficiently thin-shelled that external dark bands may show through into the interior; sometimes slightly glossy.

Soft Tissues: Off-white to tan; foot reduced; mantle lobes fused forming two siphon-like structures.

HABITAT: Zebra mussel may occur on many bottom types, but generally attach to solid structures, including crustaceans and other mollusks (Schloesser 1992). It tolerates salinity to 12.3 ppt (Benthem 1943), but prefers levels less than 1 ppt (Wolff 1969). It generally occurs within 1-2 m of the surface, but has been found to depths of 50 m (O'Neill and MacNeill 1991). The larval stage is planktonic, juveniles may crawl about the bottom during their first year, then become sessile thereafter; young specimens may actually migrate into deeper waters to overwinter (O'Neill and MacNeill 1991).

SPAWNING: Spawning occurs above 13°C, with peaks at 22°C (Hebert et al. 1989); however, veligers have been taken at temperatures as low as 8.5°C (O'Neill and MacNeill 1991). Egg production may continue sporadically throughout the warmer months (O'Neill and MacNeill 1991). Reproduction begins in specimens of about 10 mm (Hebert et al. 1989) but may occur in precocious specimens at much smaller sizes. Free-floating veligers may remain in the water column for 10-15 days before settling to the bottom; time from the egg to attached juveniles is often about three weeks (Hebert et al. 1989). Early life stages were described by Hopkins (1990) as veligers (0.070-0.290 mm) and post veligers (about 0.200 mm). Zebra mussels have no parasitic glochidial stage and do not require a fish host. Morton (1960) indicated all freshwater bivalves incubated eggs except Dreissena.

GLOCHIDIA: None.

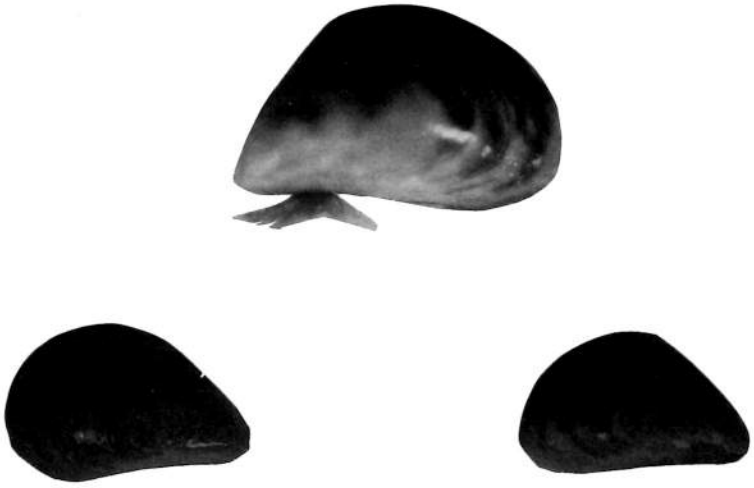
HOSTS: None.

ECONOMIC IMPORTANCE: Although zebra mussels are eaten by crayfishes and birds (O'Neill and MacNeill 1991), and no doubt by other predators like freshwater drum (Aplodinotus grunniens), they have little major positive importance in North American waters. Rather, they probably pose one of the most significant ecological threats to date. Massive populations of zebra mussels may displace unionid mussels or alter the population structure of native mussel communities (Schloesser 1992). Their function as a biofouling organism is already having impacts on industrial and urban water use by clogging water lines, attaching to commercial and recreational boats, and confounding general recreational water use (O'Neill and MacNeill 1991).

COMMENTS: Zebra mussels normally live about 3.5 years, but may reach 5 years (O'Neill and MacNeill 1991) to 6 years (Hopkins 1990). They filter feed not only on small particles and algae, but also may take rotifers and probably even their own veligers as well (MacIsaac et al. 1991). MacNeill (1990) suggested zebra mussel may be involved in the transmission of certain fish parasites.

Quagga mussel (recently identified as Dreissena bugensis) was also found to have invaded Lake Erie, Lake Ontario, and several adjacent waters in 1991, and occurs with zebra mussel (May and Marsden 1992). They report it to be similar in size and color pattern to zebra mussel, but to differ electrophoretically and in the absence of the flattened side that characterizes zebra mussel. Because its discovery is recent and it is still under study, full implications of this species have yet to be fully defined, but are probably not beneficial. Note: Recommended terminology now includes the use of "zebra mussel" for D. polymorpha, "quagga mussel" for D. bugensis, and "zebra mussels" collectively for both.

Dark falsemussel (Mytilopsis leucophaeata), which is native to North America, has been confused with zebra mussel. MacNeill (1991) reported dark falsemussel to be darker in color and usually without a banding pattern (bands sometimes vaguely suggested but never as bold as in zebra mussels), more rounded ventrally, and having a periostracum which was more easily scratched off when dry; zebra mussels usually show color patterns, are more flattened ventrally, and have a thicker epidermis which is not easily eroded. MacNeill (1991) further indicated in dark falsemussel only the anterior adductor muscle attached to the septum (which is narrower), and the retractor muscle attached to a small, inward projection of the septum (hinge lobe or apophysis), with the apophysis being absent in Dreissena. This additional lobe or plate may be small, and is positioned slightly below the level of the septum and to one side (magnification may be necessary for viewing).



Quagga mussel (Dreissena bugensis): Lake Erie, New York, 1993; 11-13 mm shell length; TPWD.

Family: Dreissenidae
DARK FALSEMUSSEL
Mytilopsis leucophaeata

Dark falsemussel (Mytilopsis leucophaeata): Perry R. Bass Marine Research Station pond, Calhoun County, Texas, November 1992; 11-13 mm shell length; TPWD.

OTHER COMMON NAMES: Conrads false mussel, platform mussel.

SYNONYMY: (Andrews 1981; Marelli and Gray 1983).

Mytilopsis leucophaetus Conrad 1831
Mytilus cochleatus Kickk in Nyst 1835
Mytilina cochleata Cantraine 1837
Dreissena cochleata Nyst 1843
Mytilus tenebrosus Reeve 1853
Mytilus americanus Reeve 1853
Tichogonia cochleata Dunker 1853
Dreissena cummingiana Dunker 1855
Dreissena cochleata Dunker 1858
Dreissena americana Fischer 1858
Tichogonia cochleata Kuster 1889
Tichogonia americana Kuster 1889
Congeria leucophaeta (Conrad 1831), Dall 1898
Mytilopsis leucophaeta (Conrad 1831), Dall 1898

The species name has also been spelled leucophaeta (apparently a misspelling).

DISTRIBUTION: Occurs in low-salinity brackish and fresh waters in or near coastal rivers. Occurs in coastal areas from New York to Mexico (Andrews 1981). Not widely reported for inland waters in Texas; however, found as far up the Mississippi River drainage as Illinois (Koch 1989). Large populations appeared in 1992 in ponds at the Perry R. Bass Marine Research Station, Palacios, Texas, possibly in response to unusually high rainfall and subsequent lower than normal salinities. Presence in low-quality waters of New York Harbor adjacent to Staten Island suggests a level of pollution tolerance [RGH]. Considered introduced in Europe (Marelli and Gray 1983).

DESCRIPTION: (Abbott 1968; Morris 1973; Sabelli 1979; Andrews 1981; Marelli and Gray 1983).

Size: To 18 mm shell length in Texas (Andrews 1981); reported to 21.48 mm (S.D. 2.30) elsewhere (Marelli and Gray 1983).

Shell: Elongate (classical mytilid-mussel shape); height to width ratio less than 1.24:1; partially curved; relatively thin; margins curved, but rather depressed anteriorly; beaks terminal, hinge area has a long, thin bar under the ligament, ligament external, but deeply imbedded; a shelf or septum is present under the beak where muscles attach; exteriorly rough; byssal threads present, byssal opening small, byssal threads short; pallial line is smoothly curved; externally more or less smooth, with concentric irregular growth lines.

Shell Teeth: None.

External Color: Grayish-brown to dark chestnut-brown, occasionally cream, sometimes with a purple sheen, vague banding patterns seen on some specimens, but most generally uniformly dark.

Internal Color: Dull white; not polished.

Soft Tissues: Foot moderately developed; two, short, posterior siphons present.

HABITAT: Dark falsemussel is most commonly found in low-salinity brackish or freshwater reaches of estuaries. It attaches to solid objects, often in groups; it is occasionally found in muddy salt marshes. Dark falsemussel tolerates salinity to 26.4 ppt (Otto and Wielinga 1933), with preferred ranges of 1.38 ppt (Janssen and Janssen-Kruit 1967) to 12.66 ppt (Castagna and Chanley 1973). Koch (1989) reported the species could attach to a surface, release, relocate, and reattach to another surface. Upstream limitations may be controlled by physiological tolerances of larvae (Marelli and Gray 1983).

SPAWNING: It apparently produces planktonic veliger larvae typical of marine and estuarine bivalves. Dark falsemussel does not produce parasitic glochidia or require a fish host. Siddall (1980) discussed early development of the species and indicated salinity pulses were necessary to initiate spawning.

GLOCHIDIA: None.

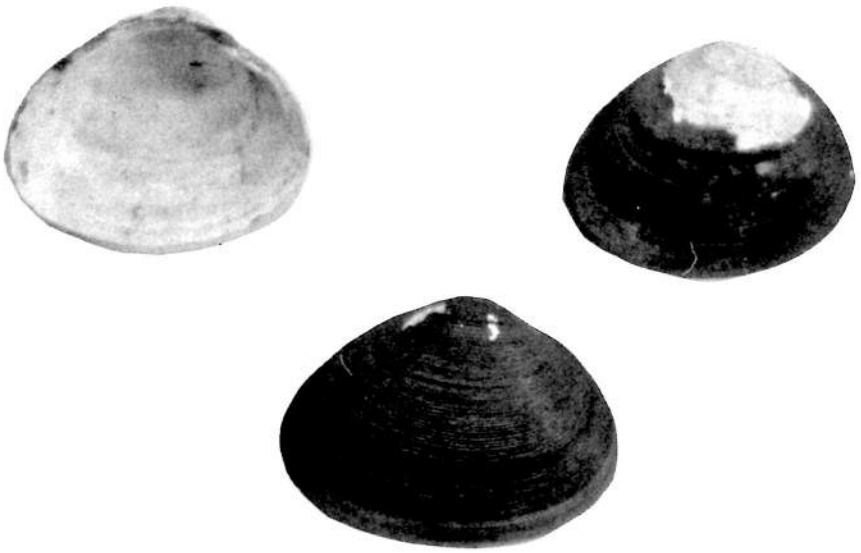
HOSTS: None.

ECONOMIC IMPORTANCE: None.

COMMENTS: This native, North American species has never proven ecologically problematic in the United States like the introduced zebra mussel (Dreissena polymorpha). It is typically small, obscure, and often unnoticed. This species has been confused with zebra mussel; preliminary reports of zebra mussels in the Hudson River and upper Mississippi River drainage were misidentified dark falsemussels. Zebra mussel have a dramatically flattened side and typically show a dark and light banded pattern; dark falsemussel is never flat-sided, and relatively uniformly colored (see zebra mussel species account). A second species in the genus, Santo Domingo falsemussel (D. sallei) has been reported from U.S. waters, but apparently not from Texas to date (Marelli and Gray 1983); it is broader dorso-ventrally (> 1.3 shell length:1 shell height) and has a wider angle at the beak (> 45°).

Dark falsemussels in the upper Mississippi River drainage may be introductions transported by barges and other river traffic. Successful reproduction in freshwater areas is apparently lacking.

Family: Sphaeriidae
FINGERNAIL CLAMS AND PEACLAMS



Fingernail clams (Family: Sphaeriidae): Pond, Cuyahoga County, Ohio, March 1973; 17 mm sl; TPWD.

OTHER COMMON NAMES: Pill clams, seed shells.

SYNONYMY: Four genera and about 38 species occur in North America (Turgeon et al. 1988); among these, several occur in Texas. Early literature sometimes placed fingernail clams along with Asian clams (Corbicula spp.) in a common family Cyrenidae or freshwater cockles (Carpenter 1861).

Murray and Roy (1968) listed the following species as reported from Texas:

- Ubiquitous peaclam, Pisidium casertanum (Poli 1791)
- Ridged-beak peaclam, P. compressum Prime 1851
- Shiny peaclam, P. nitidum Jenyns 1832
- Striate peaclam, P. punctiferum Guppy 1867
- Triangular peaclam, P. variabile Prime 1852
- Swamp fingernail clam, Musculium partumeium (Say 1822)
- Pond fingernail clam, M. securis (Prime 1851)
- Long fingernail clam, M. transversum (Say 1829)
- Striated fingernail clam, Sphaerium striatinum (Lamarck 1818)

DISTRIBUTION: Generally not common, but widely occurring across the state.

DESCRIPTION: (Clench 1959; Pennak 1953; RGH).

Size: Usually under 25 mm shell length (Pennak 1953), generally much smaller.

Shell: Round to suboval; nearly symmetrical to inequilateral; thin, often fragile; usually curved dorsally, ventrally, anteriorly, and posteriorly; beaks only slightly raised above hinge line, beak cavities relatively shallow; hinge plate absent; externally smooth except for fine concentric growth lines.

Shell Teeth: Typically two cardinal teeth (occasionally one) present in each valve, but these may be obsolete and poorly developed in some; both anterior and posterior lateral teeth present.

External Color: Off-white to tan or brown to black; often pale in color because of small size and thin shell.

Internal Color: Pale bluish-white.

Soft Tissues: Off-white to tan.

HABITAT: Fingernail clams may occur in a variety of habitats, bottom types, depths, and water conditions. Some may be abundant in or on vegetation where unionids often do not occur [RGH]. They may inhabit small ponds, lakes, streams, and rivers, and unlike typical unionid mussels, may occur in deeper waters of larger lakes (Coker et al. 1921). Eddy and Underhill (1974) reported Pisidium living in Lake Superior to depths to 122 m.

SPAWNING: All species are apparently hermaphroditic, and produce young by direct development; they ultimately release developed juveniles without a free-living larval stage (Pennak 1953).

GLOCHIDIA: None.

HOSTS: None.

ECONOMIC IMPORTANCE: All species are too small to be of commercial or sport importance, but often serve as food for fishes and other animals.

COMMENTS: Fingernail clams differ from unionid mussels by the presence of both anterior and posterior lateral teeth; only posterior lateral teeth are present in unionids. They differ from Asian clams by being smaller in maximum size and lacking the bold, concentric ridges externally on the shell. Additionally, Asian clams have fine, file-like striations on the lateral teeth that are not evident in fingernail clams. Fingernail clams may be quite abundant at some locations elsewhere; however, sampling by TPWD in Texas has thus far not found living specimens to be common at any locations sampled.

GLOSSARY

The following term definitions largely reflect those previously presented by Buchanan (1980), Burch (1973), Murray and Leonard (1962), and Oesch (1984).

ADDUCTOR MUSCLES: the muscles that close the shell; one anteriorly and one posteriorly in unionids, extending from one valve to the opposite valve.

ALA: a wing-like structure (see alate).

ALATE: having a wing-like structure; in unionids, along the dorsal margin posterior (occasionally anterior) to the beak, extends dorsal to the hinge line.

ANTERIOR SLOPE: area across the dorsal portion of the valve from the beak to the anterior margin.

ANTERIOR WING: a wing or ala positioned along the dorsal margin anterior to the beak (see alate).

ARAGONITE: one of two crystalline forms of calcium carbonate that are the main components of unionid shell (see calcite).

BEAK: the raised, inflated, or domed area of the shell along the dorsal margin; also called the umbo.

BEAK CAVITY: the cavity that extends into the beak, usually adjacent to the pseudocardinal teeth.

BEAK SCULPTURE: the pattern of ridges, pustules, lines, or corrugations on the dorsal-most portion of the beak. Beak sculpture can be an important diagnostic character in species identification; however, beak areas are often eroded and these features are obscure or absent in older specimens.

BRADYTICTIC: long-term or winter breeders or brooders; having eggs, embryos, or glochidia which are carried in the marsupia through the winter and into the spring before release. In certain species, at least some individuals in a given population may be at different reproductive stages at the same time (e.g., a spent female which just released glochidia from a previous mating may occur with another carrying recently fertilized eggs).

BRAIL (BRAILLE, BRAILE): a harvest device used to take unionid mussels; consists of a long rod, often with wheels at opposing ends, with lines or chains trailing behind and attached crowfoot hooks. The brail is pulled by a boat along the bottom; mussels projecting above the bottom and gaping open may "bite" or close on the crowfoot hooks when pulled over mussel beds.

CALCITE: one of two crystalline forms of calcium carbonate that are the main components of unionid shell; it differs in arrangement of molecules from aragonite, the other component.

CARDINAL TOOTH: an elevated, tooth-like portion of the hinge plate which interlocks with a similar structure or structures on the opposing valve; usually located below the beak. Various authors have used cardinal tooth and pseudocardinal tooth almost interchangeably; however, Murray and Leonard (1962) indicated cardinal teeth did not occur in unionids. Cardinal and pseudocardinal teeth differ in embryological development, hence indicate differing evolutionary origins [RWN].

CARUNCLE: finger-like projections of the mantle seen in female lilliputs (Toxolasma spp.).

CELT-SHAPED: said of some unionid glochidia whose shape resembles an axe-head or celt.

CHEVRON: "V" shaped markings, ridges, or grooves.

CHONDROPHORE: a spoon-shaped shelf in the bivalve hinge which holds a horny cushion of cartilage; typical of certain marine pelecypods.

CLAM: a common name used collectively for bivalves of the Class Pelecypoda (Bivalvia), as well as some families and species of bivalves; it is not specific to unionid mussels of the Family Unionidae.

CONCENTRIC: said of markings, grooves, or ridges forming rings with a common center.

CONCHIOLIN: soft material composed of proteins and polysaccharides, sometimes brown in color, forming most of the organic matrix of molluscan shell.

CONGLUTINATES: the gelatinous material enclosing glochidia either within each gill marsupium or as a discharged gelatinous mass.

CORRUGATED: wrinkled with alternating ridges and furrows.

CROWFOOT: (1) a brail (see brail). (2) the hook-like structure attached to the lines trailing from a brail or crowfoot bar; often consisting of four heavy wires twisted together each curved back on itself like a fish hook.

CROWFOOT BAR: a brail or brail bar (see brail).

CUSP: a point, projection, or elevated area associated with a tooth-like structure.

DENTICLE: a small tooth or tooth-like structure. In unionids, some references may describe two pseudocardinal teeth, one of which is small, whereas other references report one pseudocardinal tooth and one denticle for the same pair of structures.

DIOECIOUS: having separate sexes; separate male and female individuals.

EDENTULOUS: without teeth. Unionids lacking both lateral and pseudocardinal teeth are edentulous.

EMARGINATE: having a notched margin; often shallow-notched as opposed to deeply grooved or deeply cleft.

ENDEMIC: native to a particular location.

EPIDERMIS: the proteinaceous outer most of the three shell layers (see periostracum). External color patterns are contained in this layer.

EQUILATERAL: valves with the beak positioned near the center and the anterior and posterior areas of the shell generally similar in size and shape.

EXCURRENT SIPHONS: the modified tube-like posterior portion of the mantle where water, wastes, and glochidia are discharged, located above the incurrent siphon. Some species may have rather well developed tube-like siphons, but in others, this may be little more than an opening between the left and right mantles.

FLUTED or FLUTINGS: undulations or corrugated areas of alternating ridges and grooves on the shell.

FOOT: the muscular portion of the body which extends ventrally and is the primary source of locomotion in most bivalves.

GAPE: a space or opening between the valves, especially when the valves are otherwise closed.

GLOBOSE: nearly spherical or globular in shape.

GLOCHIDIUM: the larval stage of freshwater mussels (Family: Unionidae) prior to transformation to the juvenile stage.

HINGE LINE: the dorsal portion of the shell forming the pivot upon which the two valves rotate to open.

HINGE PLATE: the dorsal tooth-bearing portion of the valves.

HERMAPHRODITIC: having both sexes in the same individual at the same time.

HYPOSTRACUM: the pearly or nacreous layer of the inner shell deposited by the shell muscles; the fourth inner-most layer of the shell.

INCURRENT SIPHON: the modified tube-like posterior portion of the mantle where food and water are drawn into the mantle cavity; immediately below the excurrent siphon.

INEQUILATERAL: shells having the beaks positioned nearer the anterior margin, anterior and posterior fields not equal; inequipartate.

INEQUIPARTATE: see inequilateral.

INFLATED: greatly swollen relative to shell shape or portions of the shell (e.g., beaks inflated or shell inflated posteriorly).

INTERDENTUM: a flattened area of the hinge plate between the pseudocardinal and lateral teeth.

KNOB: a protuberance exteriorly on the shell, usually large in size and few in number.

LABIAL PALP: finger-like projections on either side of the mouth of a unionid which aid in transferring food from the gills to the mouth.

LACHRYMOSE: drop shaped or tear-drop shaped (e.g., lachrymose pustules).

LAMELLA: a thin plate or layer.

LAMELLAR: said of a structure which is thin (e.g., lateral teeth lamellar).

LATERAL RIDGE: an elevated part of the unionid shell near the center of the valve extending from the beak to the ventral margin.

LATERAL TOOTH: elongate, raised, interlocking structures on the hinge line of the valves; positioned posterior to the beak in unionids, but occur both anteriorly and posteriorly in some other bivalves.

LIGAMENT: the elastic, elongate structure that joins the two valves.

LONG-TERM BREEDER (or BROODER): applied to unionids with an extended reproductive period where eggs, embryos, or glochidia may be retained over the winter and which may be present at other times of the year; also bradytictic breeders.

LUNULE: a depressed area on some shells immediately anterior to the beak.

MALACOLOGIST: a scientist who studies mollusks; less frequently, conchologist.

MANTLE: the two soft-tissue body lobes extending from and enveloping the body and lining the inner surfaces of the two valves; they secrete the inner portions of the shell, and other major shell layers at the edge of the mantle.

MARSUPIAL SWELLING: an enlarged or inflated area (often posterio-ventrally) of the female unionid shell that provides space internally for the expansion of gills carrying glochidia.

MARSUPIUM: in unionids, areas of the gills used as a pouch to contain eggs, embryos, and glochidia.

MONOECIOUS: having both sexes in a single individual.

MUSCLE SCAR: area on the bivalve shell where major shell muscles like the adductor muscles are attached.

MUSSEL: a common term used collectively for several different groups of bivalves including freshwater mussels (Family: Unionidae) whose larvae are nearly always parasitic on a fish (or salamander) host, as well as certain marine/estuarine mussels (Family: Mytilidae), and zebra mussels (Family: Dreissenidae) whose larvae are usually planktonic.

NACRE: the iridescent, inner layer of a bivalve shell, composed primarily of crystalline calcium carbonate deposited in thin, overlapping layers; mother-of-pearl.

NACREOUS: pearly or iridescent.

NAIAD (NAIADE): freshwater mussels of the Family Unionidae whose larvae are typically parasitic on fish and where adults lack adhesive byssal threads for attachment; also called clams or mussels. This term is also applied to the larval or nymph stage of some aquatic insects.

NEPIONIC SHELL: the remains of the embryonic shell at the tip of the beak; usually missing in older specimens.

NODULE: a small node, knot, or knob exteriorly on the shell.

OBSOLETE: poorly developed, ill-defined, or lacking entirely.

OTOCYST: the organ used by mussels for balance and orientation.

PALLIAL LINE: line (and sometimes groove) on the interior of the shell generally parallel to the ventral margin where muscles from the mantle to the shell are attached.

PALLIAL SINUS: an indented area along the pallial line, typically placed posteriorly and adjacent to the posterior adductor muscle scar; absent in some species.

PAPILLA: a small finger-like projection; in unionids, typically posteriorly along the mantle margin.

PERIOSTRACUM: the proteinaceous outermost of the three shell layers (see epidermis). External color patterns are contained in this layer.

PLACENTA: the gelatinous substance enveloping one or more glochidia within the marsupial gill.

PLANKTON: small animals or plants that float or weakly swim in the water column. Note in discussion of early life history, some authorities may occasionally indicate that some non-swimming larval forms may not be planktonic when in fact they may at least float or drift in the water (as opposed to laying or crawling on the bottom).

PLANKTONIC: floating or weakly swimming in the water column.

PLICATIONS: parallel ridges, typically on the surface of the shell.

POSTERIOR RIDGE: a low ridge exteriorly on the shell running from the beak posterio-ventrally to the margin.

POSTERIOR SLOPE: area of the shell dorso-posteriorly to the posterior ridge.

POSTERIOR WING: a dorsal extension of the shell extending above the hinge line, posterior to the hinge line.

PRISMATIC LAYER: the middle, calcareous layer of the shell between the external (epidermis) and internal (nacre) layers.

PSEUDOCARDINAL TEETH: compact, sometimes triangular tooth-like structures on the hinge line below the beak; literally, false cardinal teeth (see cardinal teeth).

PUSTULES: small, usually numerous, raised structures on the external part of the shell.

PYRIFORM: pear-shaped.

RADIATING: extending outward from a central point like spokes of a wheel.

RAY: a streak or linear mark either broken or continuous; often in a radiating pattern in unionids.

REST PERIODS OR LINES: the darker or thicker parts of the shell formed during periods of rest (little or no growth), typically in concentric rings.

RIB: a raised portion of the shell usually extending from the beak to the ventral margin.

SCAR: an impression on the nacre formed by the attachment of a muscle.

SCULPTURING: natural surface markings, other than coloration, on the shell including pustules, tubercles, ridges, grooves, etc.; often important in identification.

SERRATE: having sharp teeth or tooth-like structures.

SEXUALLY DIMORPHIC: said of species where males and females are obviously different morphologically as in differences in size and shape.

SINUS: a cavity or hole; also in certain unionids, a depression adjacent to the posterior ridge.

SHORT-TERM BREEDER: applied to unionids whose reproductive period is short, often only a few months; for example, species which produce and fertilize eggs, and incubate and release glochidia only during spring and summer.

SOLID: said of shells that are thick and heavy as opposed to those thin and light in weight; also of solid construction as opposed to being brittle and crumbly.

SPADIFORM: spade-shaped; specifically, glochidia which are spade-shaped.

SPATULATE: spatula or spoon shaped; broad and rounded on one end and narrow on the opposite end.

SPECIES: a group of interbreeding, or potentially interbreeding, natural populations that are reproductively isolated from other such groups.

STERILE: said of unionids or of their marsupial gill pouches when not in a reproductive state, and not necessarily implying permanent sterility for the individual.

STRIAE: slight ridges, furrows, or alternating color patterns; especially forming stripes or streaks in parallel arrangement.

STRIATE: having striae.

SUB: as a prefix, meaning nearly or almost; for example, subrectangular shells are almost but not completely rectangular in shape.

SUBSPECIES: a geographically defined aggregate of local populations within a species that differs morphologically, physiologically, or both, from other aggregations of local populations within the species.

SULCATE: having long, narrow grooves or channels, as in the depression between two pseudocardinal teeth.

SUPRABRANCHIAL CHAMBER: the dorsal portion of the unionid gills from which water and wastes are passed to the excurrent siphon.

TACHYTICTIC: summer breeders or at least short term breeders where females are gravid for short periods, often only a few months.

TRUNCATE: shells or structures appearing squared off or transversely cut off at a straight line.

TUBERCLE: a small, rounded, raised structure.

UMBO: the beak; typically the raised part of the dorsal margin.

UMBONAL CAVITY: beak cavity; the pit or cavity formed internally by the dorsal extension of the beak or umbo of the shell.

VALVE: the right or left half of a bivalve shell; two valves comprise the shell.

WATER TUBES: channels in the gills of a unionid mussel for transporting water dorsally through the gill.

WING: the usually thin, flat extension of the dorsal margin above the hinge line.

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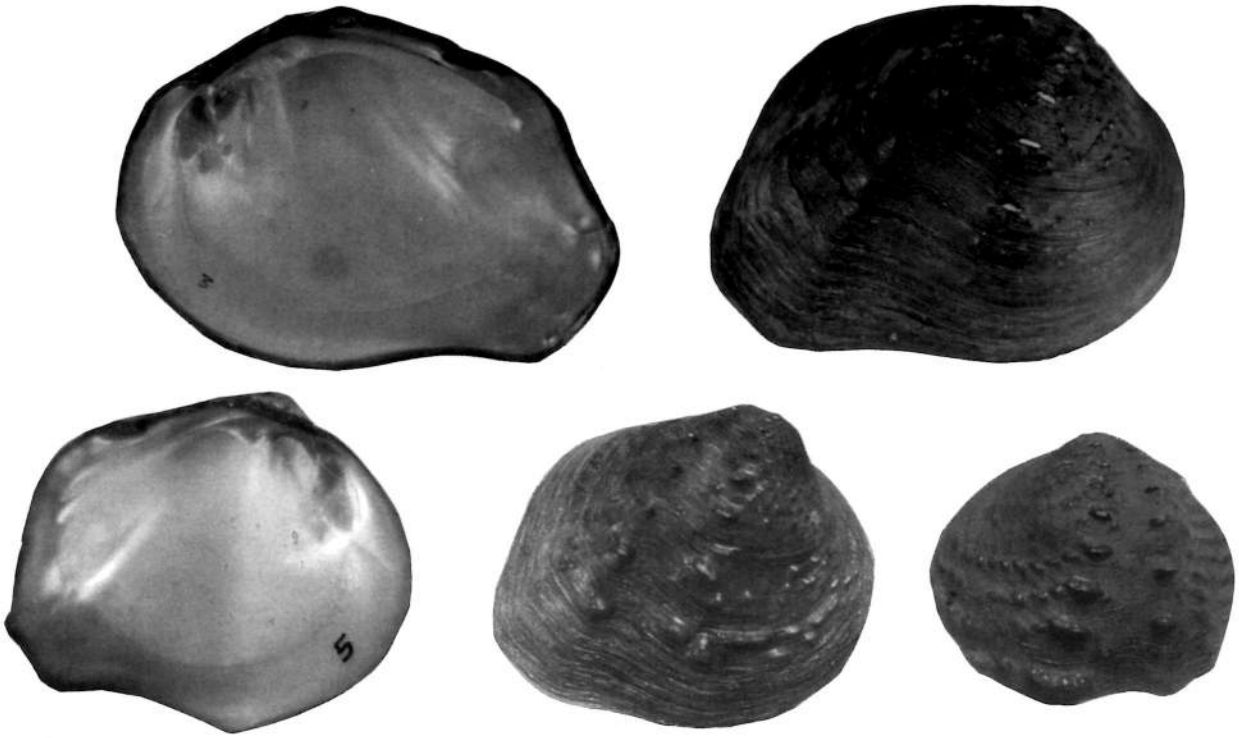
GULF MAPLELEAF
Quadrula nobilis



Gulf mapleleaf (Quadrula nobilis): B.A. Steinhagen Reservoir, Jasper County, Texas, December 1993; top 88 mm shell length, bottom left to right 63, 59, 46 mm; TPWD.

OTHER COMMON NAMES: Mapleleaf.

SYNONYMY: (RGH).

Unio nobilis Conrad 1854
Tritogonia verrucosa var. obesa Simpson 1900
Tritogonia nobilis (Conrad 1854), Simpson 1900
Quadrula obesa, Vannatta 1910
Tritogonia nobilis of Isley 1925 (?), Valentine and Stansbery 1971
Quadrula quadrula aspera (Lea 1831) in part, Strecker 1931
Quadrula quadrula (Rafinesque 1820), most recent sources (e.g., Vidrine 1993)

Recent examination of Conrad's 1854 description and illustration, Simpson's type specimen of T. verrucosa var. obesa, and recent specimens from the Neches River (Texas), Amite River (Louisiana), and Pascagoula River (Mississippi) in conjunction with electrophoretic analysis by TPWD found all to be identical to each other and genetically distinct from both mapleleaf (Q. quadrula) and southern mapleleaf (Q. apiculata). Examination of Lea's type specimen of asper found it to be the apiculata form typical of drainages to the eastern Gulf of Mexico.

DISTRIBUTION: Occurs from the San Jacinto River (based on comments by Strecker 1931) east into the Alabama River system, Alabama (D. Shelton, Mobile, Alabama; pers. comm.).

DESCRIPTION: (RGH).

Size: To at least 84 mm shell length in Texas [RGH]; to 86 mm in the Pascagoula River, Mississippi [RGH]; Simpson (1914) reported T. nobilis specimens of 80, 110, and 114 mm.

Shell: Subquadrate in smaller specimens, ovate to slightly elongate in some larger examples; inequilateral, especially in large adults; moderately inflated; thick anteriorly and thinner posteriorly, especially elongate adults; solid; dorsal margin straight or slightly curved, ventrally concave anterior to where the ridge meets the margin, rounded anteriorly, produced posterio-ventrally in larger specimens, more or less truncated posteriorly and emarginate; beaks raised above the hinge line but often not above hinge ligament, beak cavities deep; posterior ridge prominent to widely rounded, with a relatively deep sulcus anteriorly, and often a median ridge ahead of the sulcus; growth lines often apparent externally; sculpturing horizontally-elongate pustules (not drop-shaped) and fine pimples; pustules typically occur in two rows with one row on the posterior ridge and a second row anterior to the sulcus; anterior and posterior fields with pimples random, arranged in rows, or absent; beaks may have pustules in rows as well; sulcus usually free of sculpturing but some with pimples or rarely chevron-shaped ridges; posterior dorsal margin often with parallel ridges; some larger specimens nearly apustulose.

Shell Teeth: Two left pseudocardinal teeth large, erect, rough, grooved, and triangular, often with a sharp ridge at the base of the separation between; right pseudocardinal tooth usually single, large, erect, and triangular, often with an anterior and posterior denticle; a curved ridge typically present above right pseudocardinal tooth; lateral teeth straight to slightly curved and 40-48% shell length.

External Color: Yellow-brown, becoming chestnut-brown with age, older individuals may be nearly black.

Internal Color: White; iridescent posteriorly.

Soft Tissues: Off-white to tan or flesh-colored; anterior gills not attached to the visceral mass.

HABITAT: Found in the Neches River, Texas, in relatively swift waters at 6-8 m on gravel-sand-mud bottom below B.A. Steinhagen Reservoir dam (Jasper and Tyler counties). Also present on mud and sand in B.A. Steinhagen Reservoir. Taken in the Pascagoula River, Mississippi, in slow to moderate flows at 1-2 m on mud.

SPAWNING: Unreported. Specimens from the Neches River in early May, B.A. Steinhagen Reservoir in December, and the Pascagoula River in late October were not gravid.

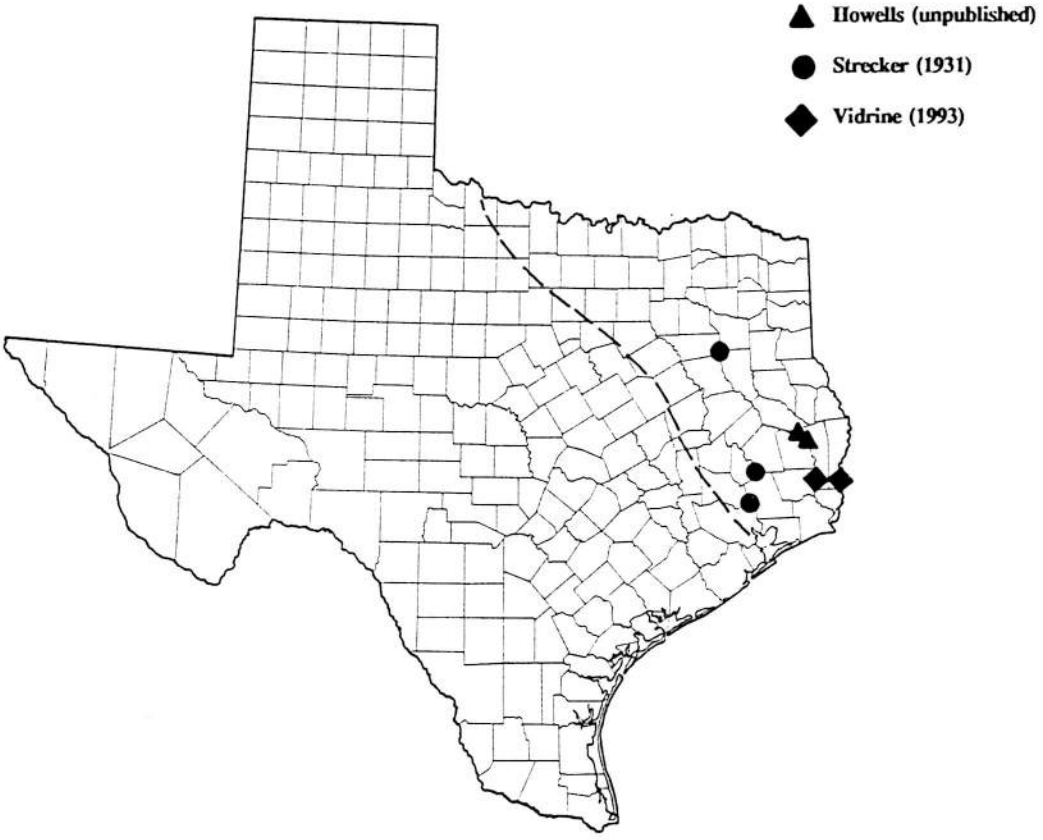
GLOCHIDIA: Unreported.

HOSTS: Unreported.

ECONOMIC IMPORTANCE: Although probably harvested with other mapleleafs for shell, it only rarely reaches harvestable sizes.

COMMENTS: Historically, Gulf mapleleaf has been confused with mapleleaf and pistolgrip. Small, quadrate specimens are easily confused with mapleleaf; however, larger, elongate adults are more distinct. Dorsal-ventral rows of pustules are horizontally elongate and almost never drop-shaped in Gulf mapleleaf; mapleleaf may also have horizontally-elongate pustules (hence Lea's original description of Unio asperrimus as a distinct species), but are more typically drop-shaped lunules. Although some mapleleafs may deviate from the subquadrate form and become somewhat elongate, they are not as produced posterio-ventrally as Gulf mapleleaf.

GULF MAPLELEAF
Quadrula nobilis



APPENDIX II: COLOR PLATES

Key:

TPWD - Texas Parks and Wildlife Department
HMNS - Houston Museum of Natural Science
TUC - Trinity University Collection
sl - shell length

THREERIDGE (Amblema plicata): B.A. Steinhagen Reservoir, Jasper County, Texas, December 1993; 82 mm sl; TPWD.

THREERIDGE (Amblema plicata): Lake Gonzales, Gonzales County, Texas, May 1993; 123 mm sl; TPWD.

THREERIDGE (Amblema plicata): Lake Buchanan, Llano County, Texas, August 1993; 61 mm sl; TPWD.

THREERIDGE (Amblema plicata): Guadalupe River, Gonzales County, Texas, August 1993; top 79 mm sl, bottom 92 mm sl; TPWD.

GIANT FLOATER (Anodonta grandis): Sabine River, Rains County, Texas, August 1993, 113 mm sl; TPWD.

GIANT FLOATER (Anodonta grandis): Cibolo Creek, Bexar County, Texas, September 1993; 113 mm sl; TPWD.

GIANT FLOATER (Anodonta grandis): B.A. Steinhagen Reservoir, Tyler County, Texas, May 1993; clockwise from top left 111, 100, 122, and 77 mm sl; TPWD.

PAPER PONDSHELL (Anodonta imbecillis): Giddings State School Lake, Lee County, Texas, October 1993; 58 mm sl; TPWD.

PAPER PONDSHELL? (Anodonta imbecillis?): Heart of the Hills Research Station pond 2, Kerr County, Texas, July 1992; 70 mm sl; TPWD.

PAPER PONDSHELL (Anodonta imbecillis): Lake Corpus Christi, Live Oak County, Texas, November 1993; 47 mm sl; TPWD.

FLAT FLOATER (Anodonta suborbiculata): Wabash River, Illinois, 1995; 136 mm sl; TPWD.

FLAT FLOATER (Anodonta suborbiculata): Wabash River, Illinois, 1995; 136 mm sl; TPWD.

FLOATER sp. (Anodonta sp.): B.A. Steinhagen Reservoir, Tyler County, Texas, May 1993; 130 mm sl; TPWD.

ROCK-POCKETBOOK (Arcidens confragosus): Neches River, Jasper County, Texas, May 1993; 98 mm sl; TPWD.

ROCK-POCKETBOOK (Arcidens confragosus): Little Brazos River, Robertson County, Texas, September 1992; 76 mm sl; TPWD.

ROCK-POCKETBOOK (Arcidens confragosus): Sabine River, Wood County, Texas, Spring 1992; 160 mm sl; TPWD.

OUACHITA ROCK-POCKETBOOK (Arkansia wheeleri): Pine Creek, Lamar County, Texas, November 1992; 84 mm sl; J.A.M. Bergmann collection.

OUACHITA ROCK-POCKETBOOK (Arkansia wheeleri): Pine Creek, Lamar County, Texas, November 1992; 84 mm sl; J.A.M. Bergmann collection.

TAMPICO PEARLYMUSSEL (Cyrtonaias tampicoensis): Nasworthy Reservoir, Tom Green County, Texas, October 1992; 82 mm sl; TPWD.

TAMPICO PEARLYMUSSEL (Cyrtonaias tampicoensis): Lake Buchanan, Llano County, Texas, August 1993; top 88 mm sl, bottom 90 mm sl; TPWD.

TAMPICO PEARLYMUSSEL (Cyrtonaias tampicoensis): Nueces River, Live Oak County, Texas, October 1992; 97 mm sl; TPWD.

TAMPICO PEARLYMUSSEL (Cyrtonaias tampicoensis): Guadalupe River, Gonzales County, Texas, August 1993; 95 mm sl; TPWD.

TAMPICO PEARLYMUSSEL (Cyrtonaias tampicoensis): Colorado River, Runnels County, Texas, August 1993; 84 mm sl; TPWD.

TAMPICO PEARLYMUSSEL (Cyrtonaias tampicoensis): Nasworthy Reservoir, Tom Green, County, Texas, September 1992; 95 mm sl; TPWD; note pearl near margin.

SPIKE (Elliptio dilatata): San Marcos River, Gonzales County, Texas, September 1965; 87 mm sl; TUC.

SPIKE (Elliptio dilatata): San Marcos River, Gonzales County, Texas, September 1965; 87 mm sl; TUC.

TEXAS PIGTOE (Fusconaia askewi): Sabine River, Harrison County, Texas, July 1994; 63 mm sl; TPWD.

WABASH PIGTOE (Fusconaia flava): St. Croix River, Wisconsin, August 1995; 63 mm sl; TPWD.

WABASH PIGTOE (Fusconaia flava): Little Cypress Bayou, Marion County, Texas, August 1984; 47 mm sl; HMNS.

TRIANGLE PIGTOE (Fusconaia lananensis): Sandy Creek, Shelby County, Texas, July 1994; 64 mm sl; TPWD.

ROUND PEARLSHELL (Glebula rotundata): Buffalo Bayou, Harris County, Texas, July 1994; 88 mm sl; TPWD.

TEXAS FATMUCKET (Lampsilis bracteata): Elm Creek, Runnels County, Texas, August 1993; top to bottom 60 mm sl - male, 54 mm sl -female, 43 mm sl - male; TPWD.

TEXAS FATMUCKET (Lampsilis bracteata): Elm Creek, Runnels County, Texas, August 1993; top to bottom 88, 80, 78 mm sl - females; TPWD.

TEXAS FATMUCKET (Lampsilis bracteata): Elm Creek, Runnels County, Texas, August 1993; left 51 mm sl, right 60 mm sl - males; TPWD.

PLAIN POCKETBOOK (Lampsilis cardium): Mountain Fork River, Oklahoma, April 1972; 75 mm sl - female; TUC.

PLAIN POCKETBOOK (Lampsilis cardium): Lake Poygan, Winnebago County, Wisconsin, July 1994; 104 mm sl - female; TPWD.

LOUISIANA FATMUCKET (Lampsilis hydiana): B.A. Steinhagen Reservoir, Tyler County, Texas, December 1993; top to bottom 78 mm sl - male, 78 mm sl male, 65 mm -female; TPWD.

LOUISIANA FATMUCKET (Lampsilis hydiana): Navarro Mills Reservoir, Navarro County, Texas, fall 1993; top 84 mm sl - male, bottom 72 mm sl - female; TPWD.

LOUISIANA FATMUCKET (Lampsilis hydiana): Lake Gonzales, Gonzales County, Texas, August 1992; top 91 mm sl - male, bottom 79 mm sl - female; TPWD.

SANDBANK POCKETBOOK (Lampsilis satura): Neches River, Jasper County, Texas, May 1993; 103 mm sl - male; TPWD.

SANDBANK POCKETBOOK (Lampsilis satura): Sabine River, River, Panola County, Texas, July 1994; 97 mm sl - female; TPWD.

YELLOW SANDSHELL (Lampsilis teres): Elm Fork Trinity River, Denton County, Texas, September 1993; 93 mm sl; TPWD.

YELLOW SANDSHELL (Lampsilis teres): B.A. Steinhagen Reservoir, Jasper County, Texas, December 1993; 110 mm sl; TPWD.

YELLOW SANDSHELL (Lampsilis teres): Choke Canyon Reservoir, Live Oak County, Texas, January 1992; 110 mm sl; TPWD.

YELLOW SANDSHELL (Lampsilis teres): Lake Wood, Gonzales County, Texas, July 1992; both 129 mm sl, female above, male below; TPWD.

WHITE HEELSPLITTER (Lasmigona complanata): San Marcos River, Gonzales County, Texas, September 1965; 142 mm sl; TUC.

WHITE HEELSPLITTER (Lasmigona complanata): San Marcos River, Gonzales County, Texas, September 1965; 142 mm sl; TUC.

WHITE HEELSPLITTER (Lasmigona complanata): Pine Creek, Lamar County, Texas, August 1993; 149 mm sl; TPWD.

WHITE HEELSPLITTER (Lasmigona complanata): Pine Creek, Lamar County, Texas, August 1993; 149 mm sl; TPWD.

WHITE HEELSPLITTER (Lasmigona complanata): Pine Creek, Lamar County, Texas, August 1993; left 140 mm sl, right 134 mm sl; TPWD.

FRAGILE PAPERSHELL (Leptodea fragilis): Sabine River, Rains County, Texas, August 1993; 109 mm sl; TPWD.

FRAGILE PAPERSHELL (Leptodea fragilis): Leon River, Hamilton County, Texas, October 1993; 75 mm sl; TPWD.

FRAGILE PAPERSHELL (Leptodea fragilis): Lake Buchanan, Llano County, Texas, December 1993; 124 mm sl; TPWD.

FRAGILE PAPERSHELL (Leptodea fragilis): Neches River, Jasper County, Texas, May 1993; 46 mm sl; TPWD.

POND MUSSEL (Ligumia subrostrata): Giddings State School Lake, Lee County, Texas, May 1993; 70 mm sl; TPWD.

POND MUSSEL (Ligumia subrostrata): Giddings State School Lake, Lee County, Texas, October 1993; 65-69 mm sl; TPWD.

POND MUSSEL (Ligumia subrostrata): Camp Creek Reservoir, Robertson County, Texas, July 1992; top 75 mm sl, bottom 70 mm sl; TPWD.

WASHBOARD (Megalonaias nervosa): B.A. Steinhagen Reservoir, Tyler County, Texas, December 1993; 62 mm sl; TPWD.

WASHBOARD (Megalonaias nervosa): Leon River, Hamilton County, Texas, October 1993; 92 mm sl; TPWD.

WASHBOARD (Megalonaias nervosa): Little Brazos River, Robertson County, Texas, August 1992; 88 mm sl; TPWD.

WASHBOARD (Megalonaias nervosa): Lake Wood, Gonzales County, Texas, July 1992; 138 mm sl; TPWD.

WASHBOARD (Megalonaias nervosa): Lake Wood, Gonzales County, Texas, July 1992; 138 mm sl; TPWD.

WASHBOARD (Megalonaias nervosa): Lake Wood, Gonzales County, Texas, July 1992; 138 mm sl; TPWD.

WASHBOARD (Megalonaias nervosa): Little Brazos River, Robertson County, Texas, August 1992; 190 mm sl; TPWD.

WASHBOARD (Megalonaias nervosa): San Jacinto River, Montgomery County, Texas, 1988; 180 mm sl; TPWD.

WASHBOARD (Megalonaias nervosa): San Jacinto River, Montgomery County, Texas, 1988; 180 mm sl; TPWD.

THREEHORN WARTYBACK (Obliquaria reflexa): B.A. Steinhagen Reservoir, Jasper County, Texas, December 1993; top 50 mm sl, bottom 53 mm sl; TPWD.

THREEHORN WARTYBACK (Obliquaria reflexa): B.A. Steinhagen Reservoir, Jasper County, Texas, December 1993; 65 mm sl; TPWD.

THREEHORN WARTYBACK (Obliquaria reflexa): Pine Creek, Lamar County, Texas, August 1993; top 44 mm sl, bottom 35 mm sl; TPWD.

SOUTHERN HICKORYNUT (Obovaria jacksoniana): Village Creek, Hardin County, Texas, August 1980; 37 mm sl; HMNS.

BANKCLIMBER (Plectomerus dombeyanus): Sabine River, Upshur County, Texas, March 1992; 125 mm sl; TPWD.

BANKCLIMBER (Plectomerus dombeyanus): B.A. Steinhagen Reservoir, Jasper County, Texas, December 1993; top 104 mm sl, bottom 88 mm sl; TPWD.

LOUISIANA PIGTOE (Pleurobema riddelli): Village Creek, Hardin County, Texas, August 1980; 46 mm sl; HMNS.

TEXAS HORNSHELL (Popenaias popei): Rio Grande, Terrell County, Texas, January 1992; 116 mm sl; TPWD.

TEXAS HORNSHELL (Popenaias popei): Pecos River, Val Verde County, Texas, July 1968; 67 mm sl; TUC.

TEXAS HEELSPLITTER (Potamilus amphichaenus): B.A. Steinhagen Reservoir, Jasper County, Texas, December 1993; 111 mm sl; TPWD.

PINK PAPERSHELL (Potamilus ohiensis): Eagle Mountain Reservoir, Tarrant County, Texas, May 1992; 113 mm sl; TPWD.

PINK PAPERSHELL (Potamilus ohiensis): Pine Creek, Lamar County, Texas, August 1993; 91 mm sl; TPWD.

BLEUFER (Potamilus purpuratus): B.A. Steinhagen Reservoir, Tyler County, Texas, December 1993; 152 mm sl - male; TPWD.

BLEUFER (Potamilus purpuratus): B.A. Steinhagen Reservoir, Tyler County, Texas, December 1993; 104 mm sl - female; TPWD.

BLEUFER (Potamilus purpuratus): Middle Concho River, Tom Green County, Texas, May 1993; 141 mm sl; TPWD.

BLEUFER (Potamilus purpuratus): Nasworthy Reservoir, Tom Green County, Texas, August 1992; 102 mm sl; TPWD.

BLEUFER (Potamilus purpuratus): Concho River, Tom Green County, Texas, August 1992; 130 mm sl; TPWD.

SALINA MUCKET (Potamilus salinasensis): Rio Grande, Brewster County, Texas, January 1992; 79 mm sl; TPWD.

SOUTHERN MAPLELEAF (Quadrula apiculata): Elm Fork Trinity River, Denton County, Texas, September 1993; left 69 mm sl, right 60 mm sl; TPWD.

SOUTHERN MAPLELEAF (Quadrula apiculata): Nasworthy Reservoir, Tom Green County, Texas, October 1992; 72 mm sl; TPWD.

SOUTHERN MAPLELEAF (Quadrula apiculata): Little Brazos River, Robertson County, Texas, July 1992; top 48 mm sl, bottom 50 mm sl; TPWD.

SOUTHERN MAPLELEAF (Quadrula apiculata): B.A. Steinhagen Reservoir, Tyler County, Texas, December 1993; 58 mm sl; TPWD.

SOUTHERN MAPLELEAF (Quadrula apiculata): Elm Creek, Runnels County, Texas, August 1993; top 60 mm sl, bottom 62 mm sl; TPWD.

SOUTHERN MAPLELEAF (Quadrula apiculata): Cedar Creek Reservoir, Kaufman County, Texas, June 1992; top 61 mm sl, bottom 40 mm sl; TPWD.

SOUTHERN MAPLELEAF (Quadrula apiculata): Nasworthy Reservoir, Tom Green County, Texas, April 1992; 37 mm sl; TPWD.

GOLDEN ORB (Quadrula aurea): Lake Corpus Christi, Live Oak County, Texas, November 1993; top 49 mm sl, bottom 45 mm sl; TPWD.

GOLDEN ORB (Quadrula aurea): Lake Corpus Chirsti, Live Oak County, Texas, November 1993; 65 mm sl; TPWD.

GOLDEN ORB (Quadrula aurea): Guadalupe River, Gonzales County, Texas, May 1993; top 47 mm sl, bottom 44 mm sl; TPWD.

GOLDEN ORB (Quadrula aurea): Guadalupe River, Gonzales County, Texas, May 1993; 38 mm sl; TPWD.

RIO GRANDE MONKEYFACE (Quadrula couchiana): Las Moras Creek, Kinney County, Texas; May 1898; 31 mm sl; HMNS.

RIO GRANDE MONKEYFACE (Quadrula couchiana): Las Moras Creek, Kinney County, Texas; May 1898; 31 mm sl; HMNS.

SMOOTH PIMPLEBACK (Quadrula houstonensis): Brazos River, Brazos County, Texas, 1949; 49 mm sl; HMNS.

SMOOTH PIMPLEBACK (Quadrula houstonensis): Little Brazos River, Robertson County, Texas, September 1992; 57 mm sl; TPWD.

SMOOTH PIMPLEBACK (Quadrula houstonensis): Inks Lake, Llano County, Texas, July 1992; 58 mm sl; TPWD.

PIMPLEBACK SPP. (Quadrula spp.): Eagle Mountain Reservoir, Tarrant County, Texas, June 1993; top 50 mm sl, bottom 38 mm sl; TPWD.

WESTERN PIMPLEBACK (Quadrula mortoni): Neches River, Jasper County, Texas, May 1993; 46 mm sl; TPWD.

WESTERN PIMPLEBACK (Quadrula mortoni): Neches River, Jasper County, Texas, May 1993; top 55 mm sl, bottom 46 mm sl; TPWD.

WESTERN PIMPLEBACK (Quadrula mortoni): Neches River, Jasper County, Texas, May 1993; top 56 mm sl, bottom 50 mm sl; TPWD.

WARTYBACK (Quadrula nodulata): Neches River, Jasper County, Texas, May 1993; both 55 mm sl; TPWD.

WARTYBACK (Quadrula nodulata): Sanders Creek, Lamar County, Texas, August 1993; 43 mm sl; J.A.M. Bergmann collection.

TEXAS PIMPLEBACK (Quadrula petrina): Concho River, Concho County, Texas, June 1993; 43 mm sl; TPWD.

TEXAS PIMPLEBACK (Quadrula petrina): Concho River, Concho County, Texas, June 1993; 78 mm sl; TPWD.

TEXAS PIMPLEBACK (Quadrula petrina): Concho River, Concho County, Texas, June 1993; 68 mm sl; TPWD.

TEXAS PIMPLEBACK (Quadrula petrina): Blanco River, Blanco County, Texas, July 1993; 68 mm sl, TPWD; gravel-bar morph.

PIMPLEBACK (Quadrula pustulosa): Sanders Creek, Lamar County, Texas, August 1993; 43 mm sl; J.A.M. Bergmann collection.

PIMPLEBACK (Quadrula pustulosa): Kentucky Lake, Tennessee, 1992; 92 mm sl; TPWD.

MAPLELEAF (Quadrula quadrula): Pine Creek, Lamar County, Texas, August 1993; top 59 mm sl, bottom 52 mm sl; TPWD.

MAPLELEAF (Quadrula quadrula): Pine Creek, Lamar County, Texas, August 1993; 93 mm sl; TPWD.

GULF MAPLELEAF (Quadrula nobilis): B.A. Steinhagen Reservoir, Jasper County, Texas, December 1993; both 85 mm sl; TPWD.

GULF MAPLELEAF (Quadrula nobilis): B.A. Steinhagen Reservoir, Jasper County, Texas, December 1993; 46 mm sl; TPWD.

FALSE SPIKE (Quincuncina mitchelli): Llano River, Mason and Llano Counties, Texas, September 1974; 59 mm sl; HMNS.

SQUAWFOOT (Strophitus undulatus): San Marcos River, Gonzales County, Texas, September 1965; 92 mm sl; TUC.

LILLIPUT (Toxolasma parvus): Pat Mayse Reservoir, Lamar County, Texas, August 1993; 23 mm sl; TPWD.

TEXAS LILLIPUT (Toxolasma texasensis): Giddings State School Lake, Lee County, Texas, October 1993; top 43 mm sl - male, bottom 31 mm sl - female; TPWD.

TEXAS LILLIPUT (Toxolasma texasensis): Lake Corpus Christi, Live Oak County, Texas, October 1993; top 37 mm sl - male, bottom 30 mm sl - female; TPWD; mearnsi type.

PISTOLGRIP (Tritogonia verrucosa): B.A. Steinhagen Reservoir, Jasper County, Texas, December 1993; 113 mm sl - female; TPWD.

PISTOLGRIP (Tritogonia verrucosa): Leon River, Comanche County, Texas, October 1993; 161 mm sl - female; TPWD.

PISTOLGRIP (Tritogonia verrucosa): Leon River, Comanche County, Texas, October 1993; 80 mm sl - male; TPWD.

PISTOLGRIP (Tritogonia verrucosa): Guadalupe River, Gonzales County, Texas, August 1993 81 mm sl; TPWD.

PISTOLGRIP (Tritogonia verrucosa): Sabine River, Upshur County, Texas, March 1992; 130 mm sl; TPWD.

MEXICAN FAWNSFOOT (Truncilla macrodon): Rio Grande, Val Verde County, Texas, January 1972; 36 mm sl; TUC.

FAWNSFOOT (Truncilla donaciformis): Muskingum River, Ohio, August 1952; 38 mm sl; TUC.

FAWNSFOOT (Truncilla donaciformis): Neches River, Jasper County, Texas, May 1993; 13 mm sl; TPWD.

TEXAS FAWNSFOOT (Truncilla macrodon): rice canal, Fort Bend County, Texas, August 1970; 40 mm sl; HMNS.

TEXAS FAWNSFOOT (Truncilla macrodon): rice canal, Fort Bend County, Texas, August 1970; 45 mm sl; HMNS.

TEXAS FAWNSFOOT (Truncilla macrodon): "San Angelo area," Tom Green County, Texas, early 1990s; 55 mm sl; San Angelo Nature Center collection; no collection data.

TEXAS FAWNSFOOT (Truncilla macrodon): Brazos River, Brazos County, Texas, August 1994; 47 mm sl; TPWD.

DEERTOE (Truncilla truncata): Sabine River, Rains County, Texas, August 1993; 60 mm sl; TPWD.

DEERTOE (Truncilla truncata): Sabine River, Rains County, Texas, June 1994; 64 mm sl; TPWD.

DEERTOE (Truncilla truncata): Salt River, Tennessee, July 1980; 65 mm sl; TUC.

TAPERED PONDHORN (Uniomerus declivis): Giddings State School Lake, Lee County, Texas, October 1993; 111 mm sl; TPWD.

TAPERED PONDHORN (Uniomerus declivis): Brazos Bend State Park, Fort Bend County, Texas, November 1980; 121 mm sl; HMNS.

TAPERED PONDHORN (Uniomerus declivis): Middle Sulphur River, Hunt County, Texas, June 1993; 97 mm sl; TPWD.

PONDHORN (Uniomerus tetralasmus): Camp Creek Reservoir, Robertson County, Texas, March 1992; top 77 mm sl, bottom 80 mm sl; TPWD.

LITTLE SPECTACLECASE (Villosa lienosa): Attoyac Bayou, Nacogdoches County, Texas, July 1994; 64 mm sl; TPWD.

ASIAN CLAM [Corbicula sp(p).]: several Texas locations and dates; 12-34 mm sl; TPWD.

ZEBRA MUSSEL (Dreissena polymorpha): Lake Erie, Michigan, 1990; 12-18 mm sl; TPWD.

DARK FALSEMUSSEL (Mytilopsis leucophaeata): Perry R. Bass Marine Research Station pond, Calhoun County, Texas, December 1992; 11-13 mm sl; TPWD.

Freshwater mussels (Family Unionidae) represent an important yet poorly-known group of mollusks. These animals were used for food by Native Americans, harvested by early Spanish explorers for gem-quality pearls, and some species currently serve as a source of implant material for the cultured pearl industry. Recent recognition of their importance in aquatic ecosystems as barometers of environmental quality has been associated with dramatic decline and extinction of many species. Freshwater mussels are the most rapidly declining group of animals in North America. Despite historic significance, commercial value and biological importance, freshwater mussels have received limited attention from scientists until very recently. No reference to assist in the study and identification of species in Texas has been available.

This guide represents a first-of-its-kind reference to assist both biologists and naturalists in the identification and study of freshwater mussels. *Freshwater Mussels of Texas* contains 224 pages with 226 black and white photographs, 144 color photographs and 79 line drawings covering all 52 species found in Texas waters. Introductory sections cover basic anatomy, reproduction, habitat, feeding, behavior, ecology, exploitation and biogeography. Individual species accounts address common names, classification, distribution, description, habitat, spawning, glochidia, hosts and economic importance. Other bivalve mollusks which may be found in the fresh waters of Texas are also discussed.

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